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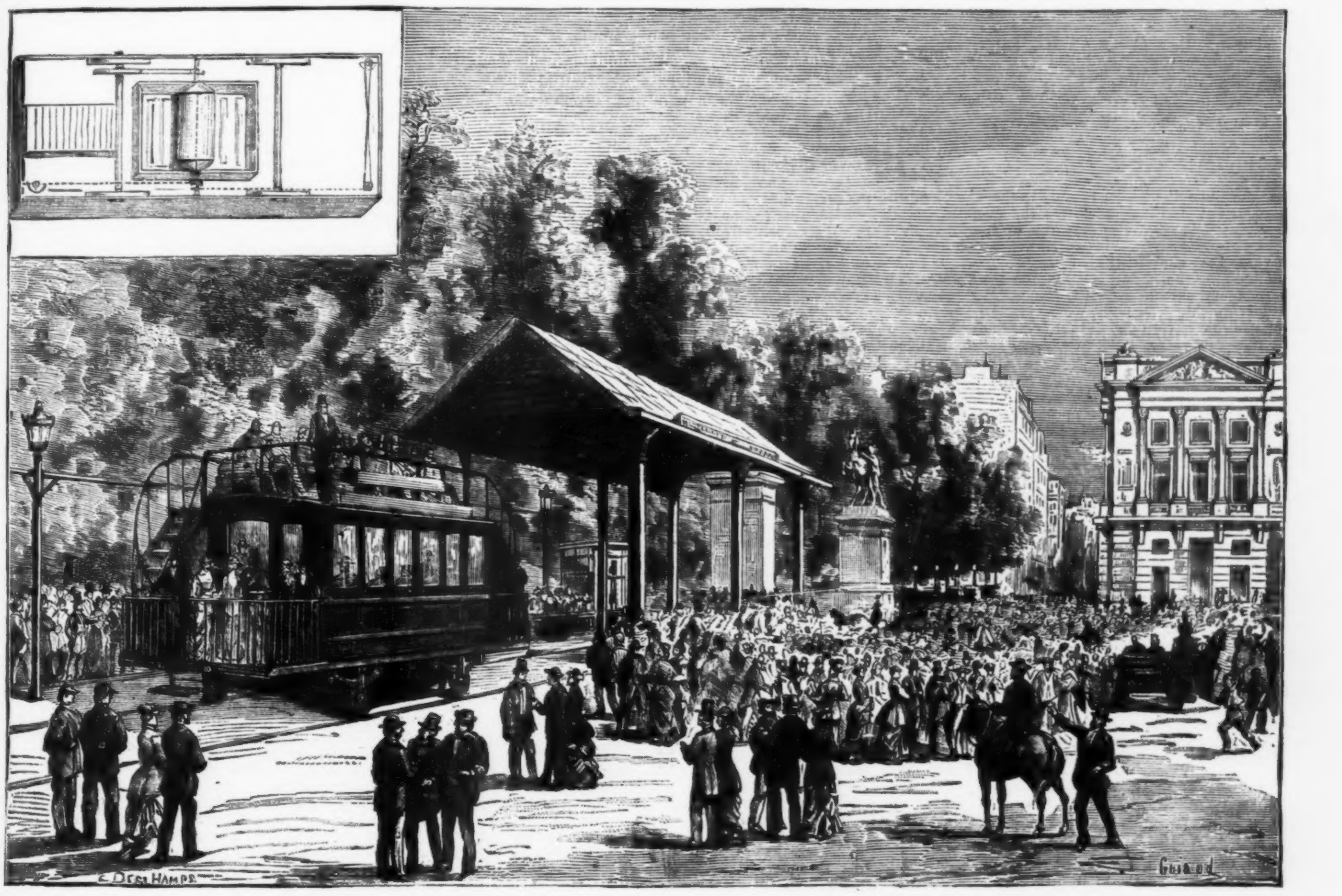


THE ELECTRICAL EXHIBITION AT PARIS.—THE ELECTRICAL RAILWAY.

SIEMENS' ELECTRIC TRAMWAY AT PARIS.

We have at length had an opportunity of riding in the Messrs. Siemens electric car running from the Place de la Concorde to the Exhibition building. It has worked very well, and has proved that, in spite of the many unfavorable circumstances that have presented themselves, the problem of locomotion by electricity is finally solved.

In the very first place, we ought to say that the car in question is much larger and much heavier than that of the Berlin Railway, a specimen of which may be seen in the machine hall of the German section of the Exhibition. It is one of the Tramway Company's cars, to which has been adapted one of Siemens' dynamo-electric machines, and which has nearly the appearance of the car represented in the article that we have previously published on the Lichterfelde Railway.*

As the municipal police required that the rails should be laid like those of tramways, that is, sunken, they could not be employed as conductors. Mud and rust even prevented their being employed as a communication with the earth, and so it became necessary to fix a double line of slit tubes, on a level with the top of the car, to posts running along the track, in order to obtain a connection between the generator and the machine in the car. This connection is effected through the intermedium of two rubbers on casters running in the interior of the tubes, and of double cords (inclosing the metallic conductors) which follow the car by passing through the slit in the tubes. By reason of the small radius of the road's curve toward the Place de la Concorde, the number of posts supporting the tubes had to be increased; and it was only after numerous trials that success was obtained in solving a problem which, in other respects, was beset with great difficulties.

It is evident that this system is not adapted for a permanent application, but there was no choice to be made, and it was necessary to submit to the requirements of the municipal police department, which did not even wish to allow the curve to be lessened by causing the road to pass from one side to the other of the avenue leading to the Exhibition. In France we are ever led to criticise and to disparage, and we think we see in these drawbacks a defeat for the application of electricity to railways; but, in all justice, the blame should be laid upon the police department and not upon electricians. We suppose now that people will be convinced of the possibility of the solution of the problem, and we hope that we shall no longer hear any more of those unseemly jests with which unsuccessful attempts in recent times have been received.—*Journal Universel d'Electricité.*

* See SCIENTIFIC AMERICAN SUPPLEMENT, No. 292, p. 4665.

ELECTRIC RAILWAYS AND TRANSMISSION OF POWER BY ELECTRICITY.*

By ALEXANDER SIEMENS.

When electricity was first utilized for practical purposes, the cost of producing it precluded its application to anything but giving signals or working small and delicate apparatus, requiring only weak currents to perform their functions; but by the discovery of the dynamo-electric principle, some fourteen years ago, powerful electric currents have been placed at our disposal, at a cost which enables us to transform into commercial processes a number of experiments which, up to that time, served only as illustrations of scientific lectures.

The machines which have caused this revolution in the application of electricity consist essentially of two parts—the fixed electro-magnets, by which a powerful magnetic field is created, and the revolving armature, which is connected with the commutator. When the machine is in action, the rapid motion of the copper wire through the magnetic field induces an electric current, which leaves the helix by the brushes pressing against the commutator on opposite sides. From the brushes the current passes to the electro-magnets, and afterwards to the outer circuit, where it has to perform the useful work. In traversing the coils of the electro-magnets, it increases the intensity of the magnetic field, which in its turn induces a more powerful current, and this mutual strengthening of current and magnetic field goes on until a balance establishes itself in the manner afterwards described.

The researches of Sir William Thomson, Dr. Hopkinson, Professor Ayrton, and others have proved that such machines, if properly constructed, will render in the form of electrical work up to 90 per cent. of the energy expended upon them in the form of motive power. It may, therefore, be conceded that they are very efficient transformers, and that we can hardly hope to exceed the results already obtained by the best types of dynamo-electric machines. If, instead of using such a machine to generate electricity, you send a current into it, the magnetic attraction created between the poles of the electro-magnets and the currents traversing the armature will cause the latter to rotate, and this motion can be communicated to other machinery in the usual ways. A pair of such machines, one for producing electricity and the second for re-transforming the current into motive power, can therefore be utilized for transmitting power to a distance. In order fully to understand the manner in which this transmission is effected, a large number of experiments were made at the works of Messrs. Siemens and Halske, in Berlin, by Dr. Frölich, and the results obtained were laid before the Royal Academy of Science in Berlin, by Dr. Werner Siemens on the 18th November, 1880.

* A recent lecture before the Society of Arts, London.

The principal conclusions arrived at were the following:

On applying Ohm's law to a magneto-electric machine (a machine with permanent magnets), we find that the strength of current for a given total resistance is—

$$\text{(1.)} \qquad C = \frac{n \times M \times v}{R}$$

In this formula, C signifies the strength of current; n, the number of convolutions of wire on the armature; v, the number of revolutions per minute; R, the total resistance in circuit; M, the total E. M. F. produced by the permanent magnets and the iron of the armature in one convolution of wire, when $v = 1$; this quantity will afterwards be called "effective magnetism" of the machine.

The same formula holds good for a dynamo-electric machine. In this case, however, the "effective magnetism" (M) depends on the strength of current (C), and the formula, by substituting f (C) for n (M) becomes—

$$\text{(2.)} \qquad C = \frac{v f(C)}{R}; \text{ or } \frac{C}{f(C)} = \frac{v}{R}$$

In the latter form, the very important law is expressed that the strength of the current in a given dynamo-electric machine depends only on the ratio of the number of revolutions per minute to the total resistance in circuit. If we determine, therefore, f (C) for a machine, we can calculate beforehand the strength of current it will produce with a given number of revolutions in a given resistance.

The first series of experiments was made to test the correctness of this conclusion, and the curves I., II., and III. embody the results obtained by working one of the largest "Siemens" dynamo-machine (type D_2) through various resistances at different speeds. The total resistance of the machine was, in case I., 0·435 S. U.; in case II., 0·725 S. U.; and, in case III., 7·14 S. U.

By way of comparison the curve IV. was set out from results published by Messrs. Meyer and Auerbach in "Wiedemann's Annalen," Band 8, p. 494, who had experimented with a "Gramme" dynamo-machine. As will be

seen, all these curves do not differ materially from a straight line, and, for the limits of practical working, they fully confirm the above theory. There exists, therefore, a curious similarity between magneto-electric and dynamo-electric machines. In both, the strength of current is proportionate to the ratio of revolutions per minute to total resistance, although the magnetism of the magneto machines is a constant quantity, and that of the dynamo-machines varies with the strength of current. The important difference between the two kinds of machine is that magneto machines give a current, however slow their motion is, whereas dynamo machines only begin to give a current when the ratio of number of revolutions to total resistance attains a certain magnitude.

The nature of the f (C) was then further examined, and the influence on the magnitude of the "effective magnetism" of the currents set up in the iron of the armature by its quick rotation in a magnetic field, and by the currents traversing the coils of the armature. The results arrived at are represented by the curves V., VI., VII., for the large Siemens machine, and by the curve VIII. for the Gramme machine referred to above. They show that at first the "effective magnetism" increases in proportion to the increase of current, then it deviates more and more until it very gradually reaches a maximum, and for still more powerful currents it decreases again. The latter peculiarity is to be accounted for by the fact that the iron bars of the electro-magnet cannot be magnetized beyond a certain point, whereas the diminishing influence of the currents on the magnetism in the iron of the armature increases continually with the strength of these currents. In practical applications such powerful currents are seldom met with, and it will suffice for the present purpose to assume that the "effective magnetism" gradually approaches a maximum.

When two machines, identical in their construction, are connected to transmit power, the "effective magnetism" in both should be equal, as the same current circulates through both of them. The following equations will, therefore, exist between the various quantities:

$$E_1 = n\,M\,v_1;\ E_2 = n\,M\,v_2;$$

$$C = \frac{E_1 - E_2}{R} = n\,M \times \frac{v_1 - v_2}{R};$$

$$W_1 = a \times E_1 \times C = a\ C^2\ R\ \frac{v_1}{v_1 - v_2};$$

$$W_2 = a \times E_2 \times C = a\ C^2\ R\ \frac{v_2}{v_1 - v_2};$$

$$H = a \times C^2 \times R;\ W_1 = H + W_2;$$

$$N = \frac{W_2}{W_1} = \frac{v_2}{v_1} = \frac{E_2}{E_1}.$$

In these formulæ the index 1 refers to the machine producing the current, and the index 2 to the machine giving out the power; E stands for electro motive force; n, M, v, R, C, signify the same quantities as before; a is a constant depending upon the construction of the machines; H is the heat, generated in the system; W_1 is the work expended upon the primary machine; W_2 is the work given out by the secondary machine; N is the useful effect.

In comparing these formulæ with observations, it is easily seen that they cannot be quite correct. This is most conspicuous with the formula for the useful effect, $N = \frac{v_2}{v_1}$, according to which this should be greatest the more the velocity of the second machine approaches the velocity of the first machine, whereas actual experiments show that N is a maximum for a certain velocity of the second machine, and will decrease for any greater or lesser number of revolutions of the secondary machine. The cause of this discrepancy is the influence of the so-called Foucault's currents, which are set up in the iron of the revolving armatures by the proximity of the powerful electro-magnets.

In the primary machine these currents circulate in the same direction as the currents in the covering wire of the armature, and by weakening the "effective magnetism," and, consequently, the E.M.F. E_1, they increase the work, W_1, expended upon the primary machine. In the secondary machine, however, in which the armature turns in the opposite direction, these Foucault currents circulate in the opposite direction to the currents of the armature wires, and by thus strengthening the effective magnetism and the electromotive force E_2, they diminish the work, W_2, given out by the secondary machine.

As our machines are supposed to be of identical construction, the following formula will express the relative proportion of the different quantities relating to the Foucault currents:

$$M_1 = M - ec_1;\ M_2 = M + ec_2;$$

$$c_1 = \frac{M_1\,v_1}{u} = \frac{1}{n}\cdot\frac{E_1}{u};\ c_2 = \frac{M_2\,v_2}{u} = \frac{1}{n}\cdot\frac{E_2}{u};$$

M signifies the effective magnetism, such as it would be if no Foucault currents existed; M_1 and M_2, the actual effective magnetism of the two machines; c_1 and c_2, the strength of the Foucault currents; u, the resistance through which these currents circulate; v and n having the same meaning as before; and e being a constant, depending on the construction of the machines.

If we calculate from the above equations the value of M_1 and M_2, substituting at the same time $y = \frac{e}{u}$, we have—

$$M_1 = M\,(1 - y\,v_1);\ M_2 = M\,(1 + y\,v_2);$$

and for the electromotive force of the two machines—

$$E_1 = n\,M_1\,v_1 = n\,M\,(1 - y\,v_1)\,v_1;$$
$$E_2 = n\,M_2\,v_2 = n\,M\,(1 + y\,v_2)\,v_2;$$

this gives for the current—

$$C = \frac{E_1 - E_2}{R} = \frac{n\,M}{R}\,[v_1 - v_2 - y\,(v_1^2 + v_2^2)];$$

and for the work expended and given out respectively—

$$W_1 = an\,CM_1\,v_1 + ac_1\,M_1\,v_1;$$
$$W_2 = an\,CM_2\,v_2 - ac_2\,M_2\,v_2;$$

or if we substitute $p = \frac{a}{n_2 u}$:

$$W_1 = a\,CE_1 + p\,E_1^2;\ W_2 = a\,CE_2 - p\,E_2;$$
$$N = \frac{W_2}{W_1} = \frac{E_2}{E_1}\left[1 - \frac{p}{aC}\,(E_1 + E^2)\right];$$

$$H = a\,C\,(E_1 - E_2);\ F_1 = p\,E_1^2;\ F_2 = p\,E_2^2;$$
$$W_1 = W_2 + H + F_1 + F_2.$$

In these formulæ the symbols have the same signification as before, and F_1 and F_2 signify the work done by the Foucault currents.

The electrical quantities E_1, E_2, and C admit of an easy measurement, and by the help of the above formulæ, the quantities W_1 and W_2 can be determined beforehand, when the constants of the machines are known.

A great number of experiments were then made, in which all the quantities were measured, and the observed results were compared with the quantities calculated from the above formulæ, and it was found that they agreed very well. It is hardly necessary to observe that these formulæ are applicable to all types of dynamo-electric machines, whatever their construction may be, the character of each type determining the constants.

The idea of utilizing these machines for transmission of power presented itself to Dr. Werner Siemens as long ago as 1867, when he discussed at the Paris Exposition with other members of the jury the possibility of elevated electric railroads; but the dynamo machine was at that time not sufficiently developed to admit of a practical execution of the idea, and when the present more perfect forms were invented electric lighting monopolized for a time all the attention that was bestowed upon the practical application of the machines.

During the efforts which have been made to introduce electric lighting on a large scale, the idea of applying the light-giving machines during day-time to distribute power, has come to the front again, and as such an application means a further utilization of the invested capital, the combination of lighting with transmission of power is sure to be made.

For this purpose a central station has to be established in a district in which powerful steam engines, working on the most economical principles, drive a number of dynamo machines, which produce the electric currents. Secondary batteries, similar to those constructed by M. Planté, and improved by M. Faure, may be employed to receive the electricity, and keep it ready for use in the same manner as the gas is stored in large gas-holders, and as accumulators are used in connection with hydraulic machinery.

From the station cast-iron pipes are laid through the streets, similar to those now in use for distributing gas or water, and insulated wires are drawn into them for conveying the currents from the machines to their destination. At convenient intervals the wires are made accessible by so-called "road boxes," inserted in the pipes, from which the connection to houses or lamp-posts can be made. Two separate sets of wires would be required for the lighting and for the transmission of power, the commutators for directing the currents being placed in the station; and additional commutators could be fixed in the houses for switching the current from secondary machines to lamps without communicating with the station.

There is no doubt that much has to be learnt before all the details of such a central station, and of a practical system of distribution have been brought to perfection; but there are, nowadays, few obstacles that cannot be surmounted, and even our present knowledge is advanced enough to teach us that there is nothing impossible in the idea sketched out above.

When a certain amount of power has to be transmitted by electricity to the given distance, it is easy to determine, experimentally, what power is required to drive the primary machine, as the exact conditions, under which the trial was conducted, can be readily reproduced in the practical application. In this respect, the transmission of power by electricity possesses a great advantage over the transmission of power by water or air, as the friction and leakage of the pipes, through which the latter have to be conducted, can never be determined in advance. It further has the advantages that the secondary machine works without producing any waste which has to be disposed of, and that the small size and low weight of the machines obviate the necessity of heavy foundations for them.

In considering the possibility of employing the electric current to distribute power from a central station, the proportion of the power given out by the secondary machine to the power expended upon the primary machine, will not be of that deciding influence, as is generally supposed. Granted even that not more than forty-five per cent. of the power expended can be reclaimed, it will still be possible to produce the power required at a cheaper rate than if each small place had its own steam-engine. For, at the central station, 1 h.p. could be produced by the large steam-engines with about 2¼ lb. of coal, so that 1 h.p. given out by the secondary dynamo machine would be produced by burning 5 lb. of coal per hour. There are few small steam engines which will produce a horse power with that expenditure of fuel, and if we take into account the trouble and risk connected with the running of steam-engines, it may be readily admitted that this loss is no real obstacle to the introduction of the electrical transmission of power. Of still less consequence will this loss be where waterfalls or other natural forces can be employed to drive the primary machines, in which case the power would cost practically nothing, beyond the interest on the capital and the depreciation of the machines. The applications which it has hitherto found have, to a certain extent, been of a tentative nature only, and on a small scale, but they are nevertheless very instructive, as they show that economical results can be obtained by it.

About three years ago Sir William Armstrong erected a turbine at his country seat, Craigside, near Newcastle, and drives by it a Siemens dynamo-electric machine, the current of which is conducted to his residence about half a mile distant from the waterfall. In day-time this current transmits the power of the turbine to the house, where it is used for various purposes, and at night it is converted into light by means of "Swan" lamps, of which it works between thirty and forty. This application deserves special mention, because it is one of the earliest examples of transmission of power by electricity for practical and permanent purposes.

In the same way Dr. Siemens utilizes some dynamo machines at his country house near Tunbridge Wells, the power to drive the primary machines being, in this case, obtained by means of a Tangye "Soho" steam-engine. The waste steam from the engine is utilized to warm the hothouses, and the gardener attending the houses takes also care of the steam-engine and the dynamo machines driven by it. In this way the cost of fuel and of attendance is reduced to a minimum.

The electric current is utilized during the whole of the night to produce two lights, by the influence of which various fruits and plants are growing; and the current, in daytime, from one machine sets in motion a similar machine, which works the chaffcutter and some other machinery at the farm about a quarter of a mile away from the hothouses. The current from the other machine is conducted to the pumping house, a distance of about half a mile, and the secondary machine there has supplanted a small vertical steam-engine that used to pump the water up to the house. In this case the return conductor is formed by the wire fence, care being taken to connect the wires from one side to the other of the intervening gates.

By these arrangements one man at the farm can do the work of three; and, instead of a man having to drive a steam-engine at the pumping-station, to say nothing of transporting coals there, and losing time in getting up steam, he can set the pump in motion without going near the place, an occasional visit only being required for refilling the lubricators.

There are many similar instances in which it is advantageous to connect a number of small machines, which work at irregular intervals, by means of the electrical transmission of power with one steam-engine, not only when the distance between the machines is considerable, but also when they are comparatively close together.

Several applications of the latter nature have been made at Messrs. Siemens' works at Charlton; among others the apparatus for testing the mechanical strength of cables is set in motion by a dynamo machine; and a small pump, which keeps the water in circulation in the core-tanks, is driven by another machine. It both cases it would have been more costly to transmit the necessary power in the usual way by shafts and belting. A few months ago a machine was placed upon a crane on the wharf, and it was found that by it a ton could be lifted about twelve feet per minute, and smaller weights proportionately quicker. It is only fair to add that the crane was not constructed for the purpose, and that the arrangement was made more with the view to demonstrate the possibility of working cranes by electricity, than to obtain the best results.

The electrical transmission of power, on account of the compactness of the machines and the ease with which the conducting cables can be shifted, is particularly adapted to be used in cases where the driven machinery is erected only for temporary purposes. As an example, it may be mentioned that, when the cable ship Faraday was last at the works of Messrs. Siemens, the machinery, by which the cable is pulled on board, was driven part of the time by a dynamo-electric machine.

Another illustration of the same kind was furnished by M. Felix, of Sermaize-les-Bains (Marne), who worked, in June, 1879, one of Howard's double-furrow plows by a Gramme dynamo machine. The motion was conveyed from the electrical machine to a drum, and thence by a coil of wire to the plow. There was no stoppage of any kind, but the plow did its work steadily, digging up the ground to the depth of about eight inches. In the following year, M. Felix showed, at the local agricultural exhibition at Bar-le-duc, a plow and a thrashing machine, both worked by electrical transmission of power, with perfect success.

As mentioned above, one of the first thoughts of Dr. Werner Siemens was to employ dynamo-electric machines for working elevated railroads, but it was only about three years ago that he was induced to take the matter into serious consideration, by the owner of a coal mine asking him to design a locomotive to draw the coal wagons in the mine. The result was that Messrs. Siemens & Halske showed at the Berlin Exhibition, in the summer of 1879, the model of an electric railway, which has since been exhibited at Dusseldorf and Brussels, and is at present working in the Crystal Palace. The total length of this circular railway was at Berlin 300 meters, and the gauge one meter. A dynamo machine, mounted on a carriage by itself, served as locomotive, and the passengers were conveyed in three carriages, each having seats for six persons. The current was conveyed from the primary machine to a rail laid between the rails on which the carriages run; thence it was taken off by brushes fixed to the machine, and, sliding on the center rail, it returned to the primary machine by the outer rails. When the carriages were prevented from moving, the locomotive exerted a pull of about 4 cwt. (200 kilos) on them; and when the train was in regular motion, the pull varied between 1½ cwt. and 1¾ cwt. (70–80 kgr.), which represents, as the speed was about 10 feet (3 meters) per second, three-horse power.

Small as the railway was, it clearly demonstrated that such a mode of transport is feasible; and the advantages of having light carriages, of being able to propel them without noise and smoke, induced Messrs. Siemens & Halske to lay before the authorities in Berlin a plan to make an elevated railway through one of the streets in Berlin, altogether about 6¼ miles (10 kilom.) long.

Along the curbstones of the street, iron columns, formed by two-channel irons, were to be erected, about 11 yards apart, carrying wooden sleepers on top, which, in their turn, support longitudinal girders. To insure the stability of the structure, wooden struts keep the girders apart, and serve, at the same time, to insulate them from each other. The clear height, from the level of the street to the under side of the girder, is about 14 ft. 6 in. (4·4 meters), and the depth of the girder about 16 in. (40 cm.) Steel rails are laid on top of the girders, and the girder and rail on one side serve as the conductor from the primary machine, and the other rail and girder form the return wire; in this way the electrical resistance of the line is reduced to a very low figure.

The gauge of the line was to be one meter, and the carriages, resembling ordinary tram-cars, were to be about 5 ft. 5 in. broad (1·65 m.) and 8 feet (2·46 m.) high above the rails. The dynamo machine, placed out of sight, underneath the car, imparts the motion by means of belts to the two wheels, which have to be insulated from each other, as the current arrives through one rail, passes through the machine, and returns by the other rail as described above.

The speed at which these carriages were intended to travel is 30 kilometers (18·6 English miles), and ten of them were to be supplied for the railway, of which six would be in use, and four in reserve, 10 horse-power being required to drive the primary machine of each carriage. The cost was carefully worked out, and, as it serves as an indication what such railways may be expected to cost, a short summary of the principal items will not be out of place.

First cost of 10 *kilometers* (6¼ *miles*), *elevated railway, single line.*

Railway itself, including ten stations	£61,000
Ten carriages, to hold fifteen persons each	3,150
Stationary steam engine and dynamo machine	1,950
Buildings	1,185
Land	4,500
General expenses	715
	£72,500

or about £11,600 per mile.

This estimate includes the cost of erection of the railway and of the station at which the steam-engine works, together with the necessary buildings to protect the rolling

stock against the weather when it is not used. The cost of working the railway was calculated to be, for one year:

Current Expenses.

Wages	£2,190	
Fuel	1,110	
Oil and waste	50	
Lighting	80	
		£3,420

Depreciation and Repairs.

Three per cent. on £62,500 (railway and buildings)	£1,875	
Sixteen per cent. on £5,000 (carriages and machinery)	800	
		£2,675

Interest on Capital.

Five per cent. on £72,500	£3,625
Total cost per annum	£9,720

or about £4 6s. per English mile per day.

The intention was to run about 200 trains per day, and if the charge of 1d. per mile had been made, the £4 6s. per mile could have been earned, if on the average five or six persons had been conveyed in each case. The concession for this railway was not granted, partly because the inhabitants strongly objected to having people looking into their first floor windows, and partly because the Emperor did not wish to see "The Linden," which this electric railway was to cross, disfigured.

Subsequently, Messrs. Siemens & Halske obtained permission to build a railway on the ground level from Lichterfelde, a suburban station on the Berlin-Anhalt Railway, to the Military Academy, and this railway has just been successfully opened for regular traffic. It is a single line of 1 meter gauge, a little over 1½ English miles long. The permanent way has been constructed in exactly the same way as that of railways; wooden sleepers and steel rails are employed, the rails being connected, in addition to the usual fish plates, by short straps of iron, bent in the shape of a bridge, so as to admit the adjustment of the rails to different temperatures, and to reduce at the same time the electrical resistance. As the currents are low tension currents, it was not necessary to provide further insulation, and no difficulty is experienced in using one rail as the positive and the other as the negative conductor.

About a third of a mile from the Lichterfelde station the primary machine, with its steam engine, is erected in the engine-house of the water-works, and the current is conveyed from there to the rails by underground cables. The car is exactly similar to an ordinary tram-car, and is constructed to hold twenty persons besides the guard. It is symmetrical, and can move backward and forward, each end being provided with a starting-lever for the guard, a brake handle, and a signal-bell. The dynamo machine is placed underneath the car, and transmits its movement to the wheels by means of spiral steel springs. The tires of the wheels are insulated from their axles, and are in electrical connection with brass rings fastened on the axles, but insulated from them. Contact brushes press against these brass rings, and from them the current is conducted to the dynamo machine, and sets it in motion.

The authorities were for some time doubtful how to class this novel railway, and after long deliberation they have decided to rank it as a one-horse tram-car. In consequence of this decision, the average speed on the railway must not exceed 9·3 English miles (15 kilometers) per hour, and the greatest speed at any moment must not exceed 12·4 English miles (20 kilometers) per hour. The time for traversing the whole distance is, therefore, not to be less than ten minutes, although the car could make the journey in about half the time with perfect safety.

If the railway continues to work in a satisfactory manner it is to be extended, and there is no doubt that the success of the railway at Lichterfelde will greatly assist in the further introduction of electrical railways, either on the level of the streets, or elevated, like the steam railways of New York. Over any other system, worked by steam or by compressed air, the electrical has the advantage that no heavy machinery has to be carried about to set the train in motion. The carriages can, therefore, be built in a lighter manner, thus reducing the power necessary to move them, and permitting all bridges and other superstructures to be built more cheaply than usual. Several carriages, each with a dynamo machine, can be joined to one train, and by this distribution of the motive power much steeper inclines can be overcome than when the same train is drawn by a single locomotive.

In addition to the ordinary brakes, means can be provided to short circuit the machines on the carriages, and to cause them in this way to act as very powerful brakes. The use of large stationary engines reduces the amount of fuel necessary to develop a certain power on the traveling carriage, and if waterfalls can be utilized, the cost of working these railways will be further diminished. It seems, therefore, probable that such railways can be usefully and economically constructed to facilitate the traffic in crowded streets, or in situations where local circumstances favor their application.

From all that has been done during the last few years, it is quite evident that the art of transmitting power by electricity has advanced rapidly, and that its practical application is continually gaining ground. This, however, should not be regarded as a sign that the electric transmission will supersede every other system of transmitting power to a distance, but rather that there is a sphere for it, where it meets existing demands better than our present means; and it should, therefore, not be treated as an enemy of existing systems, but as a supplement to them, by the aid of which problems can be solved that could not otherwise be attempted.

DISCUSSION.

The Chairman said the subject brought before them that evening was one which, though of the highest importance, had been presented in a modest, unassuming manner; but there was in the paper matter for very deep consideration. The great utility of some means of transmitting power to a distance had long been recognized, and must be appreciated by all who thought on the subject. The same argument was frequently made use of which had been advanced to-night, that if power could be laid on to houses in small quantities, it might turn the course of industry from the system of large factories to a system in which each workman might work in his own dwelling; but he was not at all prepared to say that such a change, except in special cases, was desirable. The probability was that the workman would have bad ventilation, that he would not attend to his duties so well as he would in a large factory, and that all the economies arising from a well-organized establishment and the subdivision of processes would be done away with, the only advantage being the somewhat sentimental one that the man worked in his own house. However, this was rather a question for the political economist than for an engineer. Attempts at transmitting power from a distance had been made for many years. He was apprenticed to an engineer (John Hague) who was the very earliest to make the attempt on a large scale. His mode was the exhaustion of air by pumps worked by water-wheels or other suitable prime movers, the exhausted mains being connected to engines in the nature of a steam engine, and the pressure which the atmosphere exerted on the piston caused it to work. In that way power was conveyed very well indeed—considering the time at which it was done—and very usefully. Notably, it was conveyed to underground engines in coal mines, where it provided a motor free from the objections of steam engines in such positions; it was also conveyed from a steam-engine into gunpowder manufactories, so as so obviate the necessity of fires within the manufactory. Since then they had had the transmission of power by compressed air, and also by water under pressure, as perfected by Sir William Armstrong, by means of accumulators and various hydraulic engines. He could not quite agree with Mr. Alexander Siemens, that the great advantage in the electric mode of transmission over these last two, lay in the fact that with them the loss by friction and leakage could not be accurately calculated; because the loss by friction was easily calculated, and that by leakage was dependent on the care with which the work was carried out, and it ought to be, and was, in fact, extremely small. Then again, there was the transmission of power by means of endless ropes, of which there was a magnificent example at Schaffhausen, where the water of the Rhine was made to work large turbines which drove endless ropes; these were carried about three-quarters of a mile along the bank of the river, and drove shafting under the side streets, from which the power was laid on to various houses, and he did not know a more interesting sight than to see the power of the Rhine thus utilized. But this evening we had before us a means of transmitting power by electricity, and no doubt if such a slender conductor as was on the table could be substituted for the large exhausted main of John Hague, for the smaller main carrying compressed air, or the still smaller one carrying water under pressure, or for the rope running over guide pulleys, a great step would be gained. Mr. Alexander Siemens had put it that this mode would be economical even supposing only 45 per cent. of the power developed in the steam engine was available at the spot where it was utilized, and did so, on account of the greater economy in working one large central steam-engine rather than a number of small ones, and in that he quite agreed with him, as also in the statement that 2½ lb. of coal per horse-power was a liberal allowance for a large condensing engine, and that at least 5 lb. were used in small non-condensing engines. He had also pointed out that where water-power was available, it might be utilized in a manner in which it could not be at present, as, instead of factories having to be built in inaccessible, out of the way places, the dynamo machines could be placed there, and connected by wires to sites where the manufactures could be carried on with comfort, and where transport was easy. He had had the good fortune to see the arrangements of Sir William Armstrong at Craigside; there was a fall of water which drove the machine, the wires were led to the house, nearly three-quarters of a mile off, and during the day the force was employed to work a saw bench, and at night for illuminating the house. He had not been there since the Swan lights were introduced; but Sir William Armstrong wrote to him a couple of months ago, saying that the lighting had been much improved since he saw it. Sir William stated that the light was perfect, so much resembling daylight that, at the time of writing, he had even been obliged to get up and draw the curtains, because there was a thrush outside trying to commit suicide by coming through the window. It appeared that the authorities at Berlin did not know how to classify this new railway; but their putting it down as a one-horse tram-car reminded him of a curious classification he heard of not long ago, when he visited the celebrated cavern near Trieste. This was lit by candles, and the landlord of the hotel complained that the electric light had been proposed, but the Prefect objected, citing a resolution which had been passed by the authorities, that neither aluminum, electricity, nor any other smoke-producing means of illumination should be employed. With regard to another mode of using electric force, which had been touched upon in the paper, he might say that he had had all the evening a most agreeable perfume coming from a melon on the table before him, which Dr. Siemens had grown by the sun, aided by electricity; and he had no doubt it would prove as good as other fruits he had tasted from the same source. In this paper they had the opening out of a subject the importance of which it was difficult to exaggerate. If, by means of electricity, they could practically convey power to a distance, and give it forth when required in anything like a reasonable proportion of the power originally employed, it was perfectly certain that they had thereby a means of utilizing the forces of nature which now are wasted. All round England they had a sea which ebbed and flowed with varying range, but probably the average would be about 15 feet; and if they could, by means of water-mills, utilize that enormous tidal force, and transmit it electrically to centers of population, they must economize the coal now employed for the purpose of motive power, and reserve it for those purposes for which, up to the present time, it would seem that coal was needed, viz., for metallurgical and other similar purposes. At the same time he by no means despaired of hearing that it was no longer needed directly even for these operations, for it was beginning to appear that electricity was able to do that, in the way of melting refractory materials, which had hitherto been done by the expenditure of fuel. The subject of the paper was so large and important, that he thought it would not be too much to ask the council of the society to devote next Wednesday evening to a continuance of the discussion.

Professor Ayrton said the first point which occurred to him on hearing the paper was in connection with the formula by which Mr. Siemens arrived at the result that the efficiency of electrical transmission ought to reach the maximum when the velocity of the motor was equal to that of the generator; but who went on to say that there seemed to be something wrong in this theoretical conclusion, because it was not borne out by experiment, and the explanation given was the Foucault currents which were set up by induction in the iron. He ventured to think there was another explanation altogether which would account for the formula not according with experimental results, and indeed he should not have predicted that the formula would agree with the results. He presumed that the experiments to which they referred were made with dynamo machines, in which the current generated by the machine was used to excite the field magnets. Now, supposing they had two dynamo-electric machines, one driven by a steam-engine, and producing a current, and the other producing work by means of that current, and imagine them running at exactly the same speed, what would be the result? There would be no current whatever passing the wire joining them; because, if running at the same speed, the electromotive force of the generator must be equal and opposite to that of the motor. But if there was even little current passing between the two machines, it was impossible for the second machine to receive power at all, since there could be no magnetization of the field magnets. And yet for the motor to revolve rapidly work must be spent in friction, even if no useful work were given out; hence it was really the use of dynamo machines which caused the theoretical result to differ from the practical. The machines which ought to be used were either dynamo-electric machines with separate exciters, or else magneto-electric machines. For the transmission of power efficiently and economically it was absolutely necessary that the magnetization of the field magnets should not be produced by the current passing through the wires joining the two machines. But when such an arrangement as he referred to was carried out, there would be little difference between the theoretical and practical result. It would be found that the economy of the transmission increased as the velocity of the motor more and more approached that of the generator; and when both velocities were extremely high, and nearly equal, the efficiency would approach very nearly to 1. There were various considerations which would bear this out. If you made experiments, as his students had done, with magneto electric machines as motors, measuring the electric energy put into the magneto-electric machine, and at the same time measuring the amount of work given out by it, you did not find that there was a maximum point after which the efficiency diminished. All the experiments he had seen showed that the efficiency increased with the speed; and he had actually obtained with a very high speed an efficiency of 92 per cent. He thought, on the whole, the conclusions Mr. Siemens had arrived at tended to show what Professor Perry and himself had advanced several times, that they ought to use either magneto-electric machines or dynamo machines, with separate exciters; and, to a certain extent, this conclusion was borne out by practical experience, because he learned that in electric lighting, which was but one mode of transmitting power, it was becoming the practice to use separate exciters for the dynamo machines; and that was the method adopted by Dr. Siemens in the city. As the chairman had pointed out, the great advantage of electricity as a means of transmitting power was not that the friction and leakage inseparable from other methods could not be calculated; but experiments seemed to show that electricity had no mass; that there was no inertia in it; and there was no waste of power in making it go round a corner, as there was with water or any kind of material fluid. In many respects, of course, the flow of electricity through a wire was like the flow of water through a pipe; the quantity of current was constant, and the electricity lost potential, just as water lost head; but there was this great difference between the two, when you had to make water go round a bend you lost a great deal of power, and the form of the bend made a considerable difference. If you had two or more bends in a pipe, in opposite directions, you lost more power than if there were a continuous curve in the same direction; but this was not so with an electric conductor, since bends made absolutely no difference in the electric resistance of a wire. The chairman had alluded to the great advantage which would result from an enormous quantity of waste power being utilized, and with that he concurred, not so much with regard to the tide, the utilization of which he feared lay in the dim future, in consequence of the great expense of storing the water when the tide rose, but rather with regard to the water-power of streams. It was quite lamentable to walk about the neighborhood of Sheffield and see the number of old grindstones which formerly were worked by water power now lying idle, the grinders having all gone into Sheffield, where they used grindstones worked by steam-power, which cost them more, but they saved on the whole, on account of the expense of transportation. If those streams could be used to work magneto-electric machines, from which the power could be conveyed into the town, and there utilized, it would be an immense advantage. There was another point about electric railways which might not have struck some of those present. At present locomotives weighed from 40 to 60 tons, necessitating very substantial and expensive bridges and permanent ways, and it was impossible to make them much lighter, or they would not have sufficient adhesion on the rails to pull a train; you could not much diminish the weight so long as you drove a train by one or two pair of driving wheels. But if you drove the train by nearly all the pairs of wheels, as could easily be done electrically, it might be made comparatively light, and there would be no loss by slip. The great value of the paper lay in its technical character; it was a laudable example of the application of principles of science to practice, which characterized all the work of the Messrs. Siemens; and if he had ventured to differ a little from some small part of the theoretical considerations advanced, he would conclude by assuring the meeting that no one more highly appreciated its practical bearing.

Mr. J. N. Shoolbred said he had made some experiments on the transmission of power, and was much struck by the remarks of Professor Ayrton on the amount of useful power the formulæ disclosed, and also as to the nature of the machines which, in his opinion, would have to be employed. He agreed with him as to the errors, which had probably arisen from the use of two dynamo machines, one as the generator and the other as the motor. He had himself long seen reason to doubt the ordinary statement that there must be a loss of 50 per cent. in the second machine, and he hoped, by some means or other, they would be able to discover the proper formula. With regard to the two classes of machines, spoken of by Professor Ayrton as the best form of primary machines, either magneto machines or dynamo machines with separate exciters, he thought—especially where the same machines were used for lighting and for transmitting power in the daytime—that dynamo machines would be chiefly employed; but they would generally fall under the condition of having one common exciter, and, consequently, according to Professor Ayrton, about 80 per cent. of the original duty given off might be recovered.

Professor Ayrton wished to explain that the figures he had used, and which were quoted in the paper, did not mean that if you gave a certain amount of power to the dynamo-electric machine you could get out 90 per cent. of that in the electric light produced by that machine; it only

meant that 90 per cent. of the power given to the machine was reproduced as electric energy. Some of that energy was employed in producing light, but a large portion—often nearly half, or more—was employed in heating the wires or the magnets.

Dr. C. W. Siemens, F.R.S., said he would only make a few remarks that evening, and speak more at length when the discussion was resumed next week. Professor Ayrton had remarked that the dynamo machine would be superseded by the magneto machine, or by a dynamo machine with a separate exciter, and he confessed that he went a long way with him in his argument; indeed, last year he communicated a paper to the Royal Society in which he showed certain defects in the dynamo machine, and suggested certain remedies. The dynamo labored under this defect, that, with an increase of work, the power to overcome the resistance diminished. The current produced by the rotation of the coils in the magnetic field had to excite the coils of the magnet itself, and the current then passed on to the second machine or to the light, to the place where the work was to be performed. Now, if that work should present increased resistance, the machine which had to overcome it should increase in energy, whereas the greater resistance caused a weakening of the current and a falling off in the power of the magnets by which the current was produced, thus causing those fluctuations which were so troublesome in electric lamps, but which, by different arrangements, had been almost overcome, and would be entirely overcome by the aid of further experience. It was quite true that in the city they were working with dynamo machines having separate exciters, but the dynamo machine could be so arranged that a portion only of the current was set aside to excite its own magnet, and if that arrangement were properly applied, he believed all the advantages of a separate exciter could be secured with a single machine. The subject especially before them, however, was the application of electricity to the propulsion of railways and the transmission of power, of which the propulsion of carriages was only one branch. Several other methods by which propulsion could be effected might be mentioned. Only a few days ago he had been in Paris, and had arranged for the construction of a short line of comparatively broad gauge, which was to be carried out by the omnibus company of Paris, in connection with the Electrical Exhibition. An ordinary tram-car would be run from the Place de la Concorde to the Exhibition, upon rails laid in the usual manner, having a suspended conductor along the side of the railway. This conductor would have a little carriage passing along it, in order to transmit the electric current from the suspended wire to the machine, and back through the rails themselves. That arrangement, which was devised by Dr. Werner Siemens, made them independent of partial insulation of the rails upon which the carriage ran, and also independent of the partial insulation of the wheels of one side from the other, leaving the rolling stock very much the same as at present, transferring the current to a separate conductor, something analogous to a single wire telegraph, upon which the contact roller ran and conveyed the current to the machine. Another arrangement by which an ordinary omnibus might be run upon the street would be to have a suspender thrown at intervals from one side of the street to the other, and two wires hanging from these suspenders; allowing contact-rollers to run on these two wires, the current could be conveyed to the tram-car, and back again to the dynamo machine at the station, without the necessity of running upon rails at all. He merely mentioned this to show that the system was not one which must be carried out in one particular way only, but was capable of very wide modification and extension according to circumstances. The paper referred to certain applications which he had made of electricity, near Tunbridge Wells, to horticulture, and on the table was a melon which had been produced by the aid of the electric light. He hoped that the chairman would take it home, and report upon it next week.

ON THE LIMITING NUMBERS OF TEETH FOR SPUR WHEELS.

By PROF. C. W. MACCORD.

I.—OUTSIDE GEARING.—EPICYCLOIDAL TEETH.

IN designing spur gearing for special purposes, it is often desirable to give the teeth such forms and proportions as to secure a given amount of receding action. Now, if the arc of recess be assigned for a wheel of a given number of teeth, there is a limit to the number which can drive it or be driven by it under that condition. It is, therefore, also desirable to have a ready means of determining whether the proposed numbers can be used or not; for although this will always appear from the diagram if the teeth are laid out, it is vexatious to find that time has been wasted in attempting what is impracticable. In order that this may be avoided, Prof. Willis, in his well-known work on the "Principles of Mechanism," has tabulated for reference the limiting numbers for both drivers and followers, and for three values of the arc of recess, viz.:

Recess = pitch, ⎫ ⎧ Epicycloidal teeth.
" = ¾ " ⎬ ⎨ Radial flanks.
" = ⅝ " ⎭ ⎩ Tooth=space.

But the utility of such tables depends upon their accuracy; and, whatever may have been the method by which the numbers above referred to were found, the results are far from reliable, and many of the figures are incorrect.

Having had occasion recently to revise these tables, we have adopted a method of determination which renders it safe to say that the amended values herewith given are practically precise.

Before presenting the new tables, however, we will briefly explain this method, because it will be found useful as a ready graphic means of ascertaining the limits under any conditions other than those there included.

The nature of the problem will be clearly seen by the aid of Fig. 1, which represents a limiting case: D is the center of the driver; C, that of the follower; and the driving tooth is just quitting contact at O.

Now, suppose the driver to be given: that is, let the number of teeth, the backlash, if any, and the arc of recess, A F, be assigned; and let it be required to find the least wheel which can be driven by it.

Having set off the arc A F from A on the line of centers, set back from F the arc F G equal to the thickness of the tooth on the pitch circle; which is known, because both pitch and backlash are given. It is clear that the driving tooth will continue longest in action when it is pointed, in which case the point will lie on the prolongation of the radius D L, which bisects F G. The face F O is to be an epicycloid, traced by the rolling upon F G of an arc, O A, of some describing circle; the center, E, of which must lie upon the line of centers, and be so situated that the arc O A shall be equal to the arc F G. The problem thus resolves itself into the finding of this point, E, which will obviously be the center of the least describing circle which can be used in the given case.

In order to find this point, we make use of Prof. Rankine's processes relating to circular arcs; which we here repeat, because they will be found exceedingly useful not only in the construction of many other diagrams relating to gearing, but for an endless variety of purposes in mechanical problems in general.

I.—In Fig. 2, let A E be tangent at A to a given arc, A B. Draw B A, produce it, and set off A G = ½ chord A B. With center G, and radius G B, describe an arc cutting A E in F. Then A F = arc A B (very nearly).

II.—In Fig. 3, let the given line, A B, be tangent at A to a given circle. Set off A D = ¼ A B; with center D, and radius D B = ¾ A B, describe an arc cutting the given circle in E. Then arc A E = A B (very nearly).

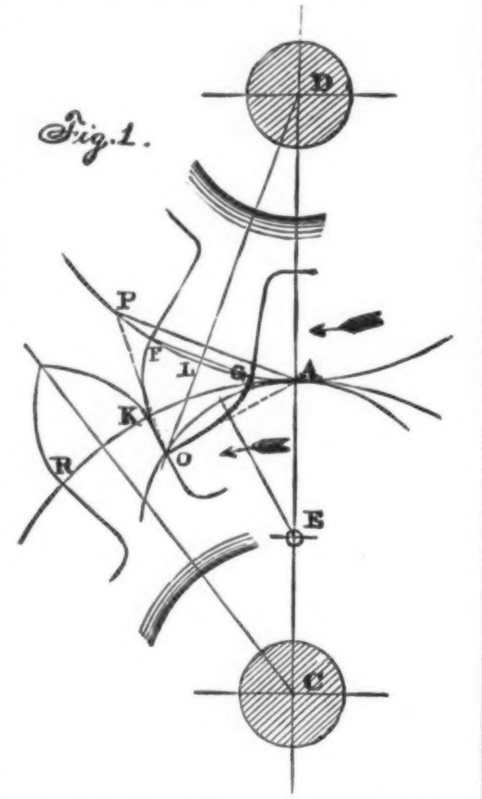


Fig. 1.

N.B.—The arc thus rectified or found should not exceed 60°. If greater, the given arc or line should be bisected, and the result thus found doubled.

Now in Fig. 4 let D be the center of the driver, A F the arc of recess, F L the half thickness of the tooth, all as in Fig. 1. Draw A G tangent, and by Process I. make it equal to the arc A F. Make A M = ¼ A G, and with center M, and radius M G, describe an arc cutting D L produced in O. Draw O A, and bisect it by a perpendicular cutting D A produced in E. Then arc O A = A G = arc A F, as required.

Having thus determined the radius, A E, of the least describing circle, that of the pitch circle to be used may be as many times greater as the judgment of the designer dictates. If the flanks are to be radial, as in the subjoined tables, we simply double A E to find the least radius of the follower, but the above process is equally applicable in all cases.

Referring again to Fig. 1, suppose now the follower instead of the driver to be given; in that case A K, the arc of recess, is equal to the arc, A O, of a describing circle, whose radius, A E, is given, so that the position, O, of the highest point of the driving tooth at the instant of quitting contact is known.

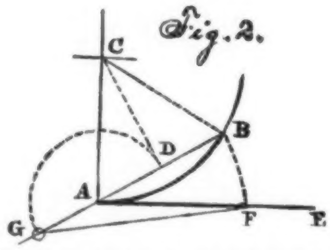


Fig. 2.

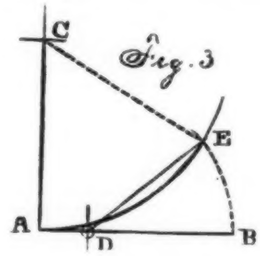


Fig. 3

Suppose the problem solved: then drawing the chord F G, and A P parallel to it, cutting the pitch circle of the driver in P, it will seen that O D bisects and is perpendicular to both F G and A P, and also that O A is equal to O P. Again, A F is equal to P G, whence

$$A P = A F + P G - F G, \text{ or,}$$
$$\text{arc } A P = 2 \times \text{arc of recess} - \text{thickness of tooth.}$$

But since the arc A F is by the conditions to be equal to A K, and F G to R K, which are given, we have all the data required for the construction shown in Fig. 5, which is as follows: Make A G, tangent to A R, equal to twice the arc A K, less the arc R K (Fig. 1); make A M = ¼ A G, and describe an indefinite arc about center M, with radius M G. About O as center, with radius O A, describe another arc, cutting the one previously drawn in P. Draw P A, and also a perpendicular to it through O; this perpendicular produced will cut the line of centers in D, giving A D the radius of the least driver which can be used.

It will be observed that the assigned conditions give all the necessary data for verifying the results of these graphic processes by trigonometrical computation; by which means the values given in the tables were determined. It may be urged in objection, that since Prof. Rankine's constructions are confessedly but approximations, the limiting radii thus found will not be absolutely accurate. And this is true, so far as it goes; but those approximations are so close (within the range of 60° of arc above specified), as to preclude the possibility of an error in the final result of such magnitude as to affect the integers.

Moreover, when the arc to be dealt with exceeds the limit named, the amount of error can be computed and a correction applied; which being done, it has been found that the computations of converse cases, in Figs. 4 and 5, which differ entirely in detail, give concordant results in every instance, in so far as the whole numbers are concerned. The values of the *radii* were always fractional, as they doubtless would be if determined with absolute precision; but since the tabulated numbers are those of teeth upon complete wheels, capable of transmitting rotation continuously in the same direction, the next higher integer is of course taken in every case.

The above explains sufficiently the operations relating to outside gear; substantially the same methods are applicable to the case of inside gearing, but with modifications and peculiarities which, in order to avoid confusion, will be separately discussed in the succeeding Section II.

The manner of using the annexed table will be best illustrated by an example or two. Suppose that the arc of recess is to be equal to the pitch; in this division are found two columns, marked D and F, for drivers and followers respectively. Let the given wheel be a driver of 12 teeth, then opposite 12 in column D we find 19 in column F, which is the least number that the given wheel can drive. If the same number be assigned for a follower, we find opposite 12 in column F the number 32 in column D, which is the least that will drive.

If the given number for a driver be not found in the table, the least follower will be opposite the next less number; for instance, a wheel of 40 teeth can drive nothing less than 12, since that can be driven by 32 or over, while 57 is the least number that will drive 11; and the same rule applies if the given number for a follower be not in the table, which includes every possible case, since under this condition (Recess = Pitch), even a rack will not drive a wheel of less than ten teeth, nor can it be driven by a pinion of less than six.

LIMITING NUMBERS OF TEETH.

RECESS=PITCH.		RECESS=¾ PITCH.		RECESS=⅝ PITCH.	
D.	F.	D.	F.	D.	F.
6	144	4	34	3	37
7	50	5	19	4	15
8	34	6	14	5	11
9	27	7	12	6	10
10	23	8	11	7	9
11	21	9	10	8	8
12	19	11	9	11	7
13	18	16	8	21	6
14	17	33	7		
15	16				
17	15				
20	14				
24	13				
32	12				
57	11				
382	10				

Outside spur gearing.
Epicycloidal teeth. Radial flanks.
Tooth=Space.

II.—INSIDE GEARING.—EPICYCLOIDAL TEETH.

In Fig. 6, let D be the center of a driving pinion, A F the arc of recess, F L the half thickness of the tooth, all as in Fig. 1. The proportions here selected are such that upon making the construction explained in connection with Fig. 4, the point, O, of the tooth thus determined falls above the common tangent of the pitch circles instead of below it. In these circumstances, it is apparent that the describing circle of which O A is a chord, must lie outside the pitch circle of the given pinion, which will be internally tangent to it, since the centers, D and E, lie on the same side of the point of contact A. The face F O of the pinion must, therefore, work against a curve formed by rolling this describing circle within the second pitch circle. In other words, the follower must be annular, and the describing circle must be an intermediate one. (See "Annular Wheels," SUPPLEMENT, No. 291.) Again, it is clear that the radius, A E, will be a *maximum* when the tooth of the driver is pointed, as in the figure: and when its value is thus found, we have for the greatest radius of the follower, as shown in the article just referred to,

$$A C = A E + A D$$

On the other hand, C, in Fig. 7, is the center of a given follower, the assigned pitch and arc of recess being such that, upon making the construction illustrated by Fig. 5, the point, P, falls below instead of above the tangent at A. In this case it is seen at once that the driver must be annular, and that its radius will be also a *maximum* when the tooth is pointed.

In these two cases, then, there is a limit beyond which the number of teeth upon an annular wheel working with a given pinion cannot be increased. And these are the only cases; for by referring to Fig. 1 it will readily be seen that any spur wheel which can either drive or be driven by another one in outside gear can also drive or be driven by a rack, or an annular wheel if the latter be not too small.

Now, if in Fig. 1 the driving pinion be given, the least describing circle is found as in the preceding Section I.; and since its radius A E cannot be greater than the line of centers if the follower be annular, the minimum radius of the annular wheel is A C=A E+A D. If the given pinion is

to be the follower, the minimum radius of the annular driver is, similarly, A D=AE+A C; but A E is in this case given, and if the follower's flanks be radial, is equal to ½ A C, so that the outer wheel can in no case be less than one and a half times as large as the internal one.

If the annular driver be given, then the minimum radius of the describing circle is found precisely as in outside gear, the diagram being shown in Fig. 8. The least radius of the follower, then, is A C=A D —A E; but supposing the follower's flanks to be radial, A C must be twice A E, whence the limitation that A E cannot exceed ⅓ A D; and if it prove greater on construction, the given conditions are impracticable.

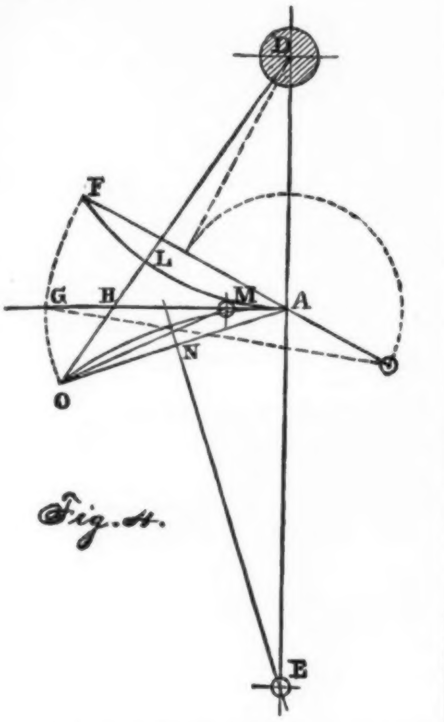


Fig. 4.

If the given pinion be the driver, we have seen that there may or may not be a limit to the increase of the number of teeth upon the annular wheel. But whether there be or not, it is evident that we need not make the tooth pointed unless we choose—that is to say, the given arc of recess can be secured with less than the maximum number, by using an intermediate describing circle less than the greatest possible one, reducing accordingly the outer pitch circle, and the lengths of the acting faces. By this means we reach what may be called a natural minimum, for the outer wheel must necessarily have at least one tooth more than the inner one, and by the above process, that may be made to suffice when the pinion drives—a fact of considerable practical importance in the arrangement of differential trains.

As previously intimated, these constructions are identical in principle with those made use of in dealing with outside

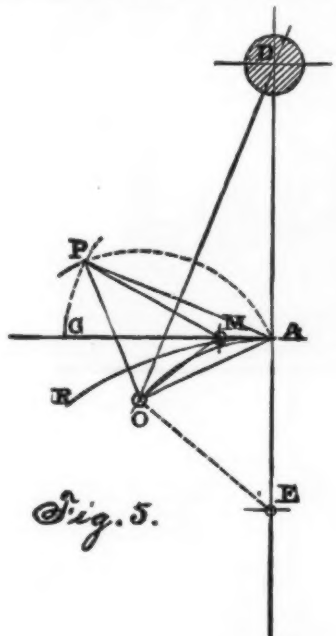


Fig. 5.

gearing, and afford the same facilities for trigonometrical computation, by which the limiting numbers given in the annexed tables were determined. These have been calculated for the same arcs of recess as in the table for external gear, given in the preceding article; but if any other arc should be assigned, the foregoing will enable the reader to make a graphic determination with great ease and accuracy.

One case has not yet been mentioned, viz., that in which the pitch, backlash, and arc of recess are assigned for an annular follower. Nor are these data sufficient for a direct solution in this case, since they do not enable us to ascertain the location of the highest point of the tooth of the required driver at the instant of quitting contact. But if the limiting numbers for the wheels be determined for various given pinions under like conditions, the problem under consideration may be solved indirectly by mere inspection of the results thus obtained. If the number upon the given annular wheel be large, this would require the tables to be inconveniently extended, were it also insisted on that the assigned arc of recess should be secured by the use of an exterior describing circle only. But if not, the least number which can be used for the pinion is at once shown by the table as

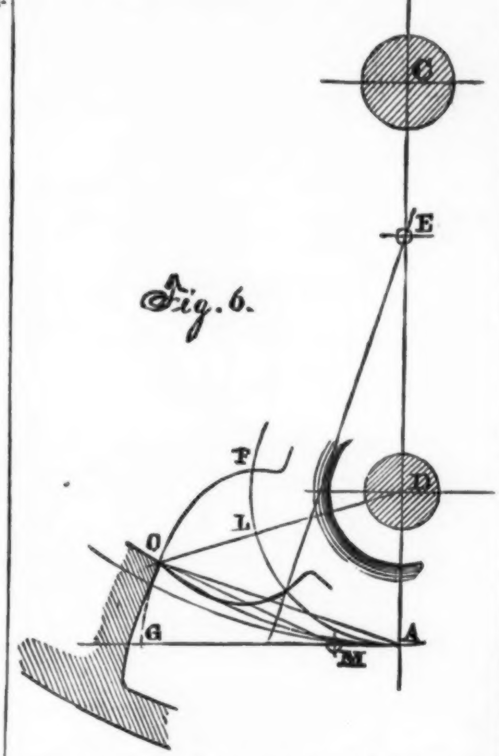


Fig. 6.

given; and the greatest number is one less than that assigned to the wheel.

In the first division of the table, marked Maximum Followers, the columns F contain the *greatest* numbers of teeth for the annular wheels, which can be driven by the pinions of the corresponding numbers in the columns D; for instance, if the arc of recess be equal to the pitch, a pinion of five can drive a wheel of forty-eight, but not more. Since the least number which can be driven is always one more than that on the pinion, it is not given in the table; it being necessary only to remark here that the lowest numbers which can be thus used are three for the pinion and four for the wheel, as a two-leaved pinion will not drive on account of the excessive obliquity when the wheel has but three teeth. The receding action in all the combinations in this division can be secured only by the use of an intermediate describing circle.

In the second division, the columns D contain the

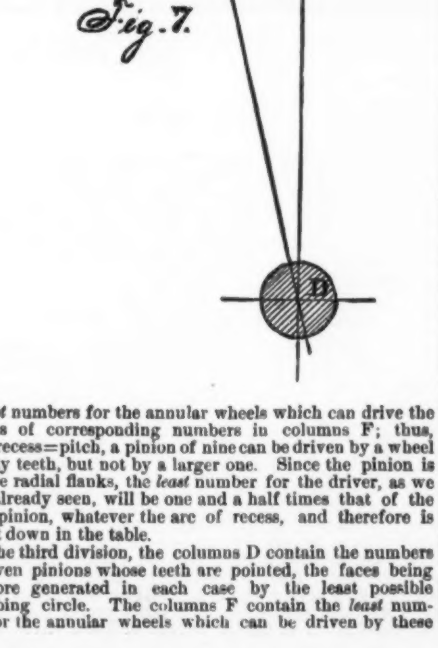


Fig. 7.

greatest numbers for the annular wheels which can drive the pinions of corresponding numbers in columns F; thus, when recess=pitch, a pinion of nine can be driven by a wheel of sixty teeth, but not by a larger one. Since the pinion is to have radial flanks, the *least* number for the driver, as we have already seen, will be one and a half times that of the given pinion, whatever the arc of recess, and therefore is not set down in the table.

In the third division, the columns D contain the numbers for given pinions whose teeth are pointed, the faces being therefore generated in each case by the least possible describing circle. The columns F contain the *least* numbers for the annular wheels which can be driven by these pinions whose faces act against flanks traced by the same describing circles, which are exterior ones; and when these least numbers are used, the annular wheels can have no faces. It would, consequently, at first sight appear that the action could only be continuously maintained when the arc of recess is equal to the pitch, since there is no approaching action. But the assigned amount of receding action in these cases is secured by the exterior describing circle only; and the actual amount is greater, owing to the peculiarity of the action, explained in the article on "Annular Wheels" previously referred to, there being in fact, up to the limit assigned in the table, two points of driving contact, so that the rotation will be properly maintained in every case.

Quite as interesting, and if anything of greater practical importance, are the questions relating to the limiting numbers for the annular wheels which can be used with given spur wheels of an interchangeable set formed by the use of a constant describing circle; and these are very readily ascertained, without the necessity of referring to a table.

In the system adopted by Brown and Sharpe, the diameter of the describing circle is equal to the radius of a pinion of

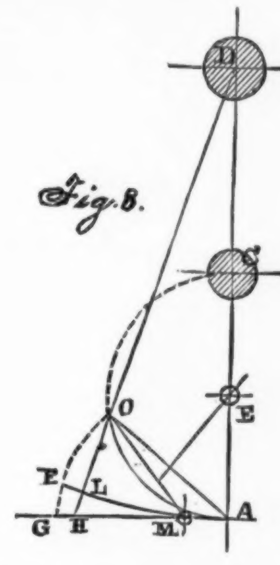


Fig. 8.

twelve teeth. If the annular wheel have both faces and flanks, the distance between the centers of the exterior and interior describing circles, then, may be represented by twelve, since the radii are proportional to the numbers of the teeth; and at the limit this distance is equal to that between the centers of the pitch circles. Therefore in these circumstances any spur wheel of the set will gear with an annular wheel having twelve teeth more than itself, but no less than that will answer. The relations of driver and follower are of no consequence, but the proportionate as well as actual amounts of approaching and receding action will depend both upon which drives, and upon the numbers of teeth. Since, however, in the use of this system no pinion of less than twelve is employed, the total angle of action will be ample in all cases.

By cutting down the pinion to the pitch line we may use a smaller wheel, and by similarly treating the wheel we may use a smaller pinion, as a driver only; the least number for the annular wheel being found in either case by adding six, instead of twelve, to the number of teeth upon the internal wheel.

In the system of Pratt and Whitney, the diameter of the describing circle being equal to the radius of the pinion of fifteen, these limiting numbers are found by adding to the number on the given spur-wheel—fifteen if both are to have faces as well as flanks; and eight, if either is to be cut down to the pitch line, since the exact number, seven and a half, to be added in the latter case, gives a fractional result, so that the next higher integer must be used.

LIMITING NUMBERS OF TEETH.

Inside Epicycloidal Gearing.

Flanks of Pinions Radial. Tooth=Space.

Recess—Pitch.		Recess—¾ Pitch.		Recess—⅝ Pitch.	
D.	F.	D.	F.	D.	F.
3 4 5 6	9 16 48 ∞	2 3 4	7 41 ∞	2 3	11 ∞
		Max. Followers.			
F.	D.	F.	D.	F.	D.
7 8 9 10	14 24 60 ∞	5 6 7	12 25 ∞	4 5	8 ∞
		Max. Drivers.			
D.	F.	D.	F.	D.	F.
6 7 8 9 10 11 12 13 14 15 16	78 32 25 23 22 22 22 22 23 23 24	4 5 6 7 8 9 10 11 12	21 15 13 13 14 14 15 16 17	3 4 5 6 7 8 9 10 11	22 12 11 11 12 12 13 14 15
		Min. Followers.			

TRIAL TRIP OF THE ALMIRANTE BROWN.

THE Almirante Brown is a twin screw armor-clad corvette, built by Messrs. Samuda Bros. for the Argentine Republic. She was launched 6th October, 1880, and fitted with engines and boilers by Messrs. Maudslay & Co., Lambeth.

She is a vessel of moderate size, combining all the latest improvements in construction, armor, and armament. The hull of the vessel is built entirely of Siemens steel; the armor is "compound" or steel-faced, consisting of an armor belt 9 inches thick at water line, and 6 inches thick below water, extending 120 feet in length and protecting the engines, boilers, and magazines. There are cross bulkheads at the ends of the belt, which reach from 4 feet below the water line to the main deck. Above the main deck amidships, is an armor-plated battery with double embrasures at the fore end, and containing in all six guns. The thickness of armor on the battery sides is 8 inches and 6 inches; that on the ends 7 inches and 6 inches. The armor plates on the belt and battery are worked on a teak backing averaging 10 inches thick. The armor plates are secured to the vessel with bolts and nuts, screwed from the inside, and so arranged as not to wound the steel face of the armor. Horizontal armor of steel plates 1½ inches thick is worked from the battery to the ends of the vessel, forming a shell-proof and water-tight deck 4 feet below the water, protecting the steering apparatus, etc. The bottom of the vessel is covered with teak planking 3 inches thick, and zinc sheathing as a protection against fouling. The vessel is fitted with a double bottom, and divided by transverse bulkheads and steel decks into numerous water-tight compartments. The vessel is rigged with two pole masts, giving an area of sail of 10,000 square feet.

machinery is so constructed that should three of the compartments be disabled the other compartment will remain intact with its complete set of pipes and valves. There are eight boilers and twenty-four furnaces. The diameter of the furnaces is 3 feet 3 inches. There are 283 tubes in each boiler, 3 inches diameter, and 6 feet 6 inches between tube plates. The grate surface is 507 square feet; the heating surface 13,674 square feet; the pressure on the safety valves 65 pounds per square inch. The engines are provided with Durham's patent velometers for preventing racing at sea.

On her measured mile trial at Maplin Sands, on 14th June, 1881, she attained the following results:

Draught forward 18·6 }
Draught aft 19·10.... } = 19·2 mean and 4,237 tons displacement, and 833 feet M. S.

Runs.	Knots.		
1 up....	15·789		
		13·914	
2 down... ...	12·040		14·021
		14·128	
3 up..	16·216		14·158
		14·187	
4 down........	12·162		13·977
		13·806	
5 up	15·451		13·991
		14·177	
6 down	12·903		——— Mean of means,
			56·167 ÷ 4 = 14·042

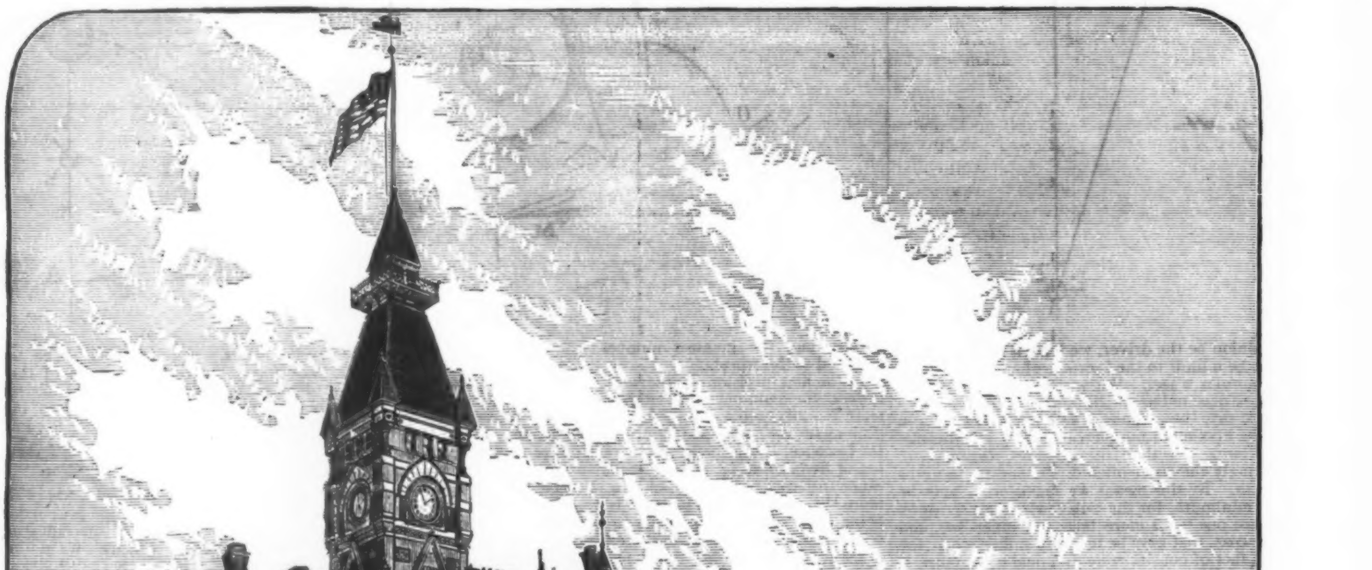
Revolutions... .... 90·05
Indicated horse-power........................ 5,400

On her six hours' trial of 16th June, the vessel being in all respects as before, the mean indicated horse-power was 5,470, revolutions 89½. So that more power and more revolutions were maintained continuously for six hours' time than on measured mile.

Mr. J. D. A. Samuda, in presiding at the luncheon on board, gave the toast of "The Almirante Brown," and stated that the corvette was the first vessel built entirely of steel, and at the same time having a coating of steel-faced armor. Nothing has hitherto been built of the same displacement, and with the same power of artillery as the Almirante Brown, which has attained the speed, averaged in the six runs, of over fourteen knots.

The ship is 240 feet long between the perpendiculars, 50 feet beam, and 21 feet 11 inches deep from the underside of the main deck to the garboard strake. She can stow 650 tons of coal, sufficient to supply the vessel when steaming at a moderate speed—say of ten knots per hour—for eighteen days, and enabling her to travel 4,300 miles.

Her armament consists of six 8-inch breech-loading 11½-ton guns in battery, capable of throwing a projectile of 180 pounds. These guns are so placed that they can be fired in a line parallel with the line of keel, one 8-inch 11½-ton gun at bow, one 8-inch 11½-ton gun at stern. These guns are all constructed on the latest breech-loading principles, and mounted on wrought iron carriages and slides, manufactured by the makers of the guns, Sir Wm. Armstrong & Co., of Elswick. Four 12-centimeter breech-loading guns, with hydraulic Albini carriage and slide on upper deck, and two ditto on battery deck; two nine-pounders for boats, and field carriage for ditto for use on shore. She is propelled by two pairs of inverted compound surface condensing engines; high-pressure cylinder 52 inches diameter, low-pressure cylinder 90 inches diameter; stroke 3 feet 3 inches; diameter of crank shaft 13¾ inches; of crank pins 14 inches; length of connecting rod 6 feet; steel piston rods 8¼ inches diameter; one air pump to each set of engines 41 inches diameter; two feed pumps ditto 6 inches diameter, two bilge pumps ditto 7¼ inches diameter; condensing surface 9,000 square feet. Each pair of engines works its own screw, and is fitted in a separate engine-room. The boilers are eight in number—oval tubular. The boiler-room is divided into four separate water-tight compartments, and the



THE NEW CINCINNATI UNION RAILWAY DEPOT.

THE CINCINNATI UNION DEPOT.

THIS structure, which will prove so welcome to Cincinnati and travelers generally, is to be located upon the corner of Central avenue and Third street. The accompanying engraving accurately represents this depot as it will appear upon completion.

The end front will be 233 feet on Central avenue. The side front will be 475 feet on Third street. On the corner of Central avenue and Third street will be an office building 80x90 feet, six stories high. This is intended to accommodate local offices for the four or five different railroads that will occupy the station. In this building there will be a series of three large fire-proof vaults on each floor. A passenger elevator and all modern conveniences for office purposes will run to the roof. There will be a light shaft in the center, affording light to all parts of the building, and at the same time a thorough ventilation. The depot proper will be approached either from Central avenue or Third street. The main passenger waiting room will be on a level with Third street, 220 feet long by 36 feet wide in the clear and three stories high, with ticket, Pullman, and telegraph offices included. There will be large and commodious parlors and living rooms and lunch counters on a level with this floor in the office building.

The passenger building will recede 30 feet back from the office building on Third street. This 30 feet will be covered over to the sidewalk with an iron canopy for the convenience of passengers alighting from carriages. In addition to this covered roadway, there will be a covered carriage and bus rotunda, 100x80 feet, opening from Central avenue.

The platform or car shed story will be 15 feet down from Third street, and will be reached by the rotunda before mentioned on Central avenue, and by a large archway 30 feet wide between the office building and main passenger room, also by a large double flight of stairs through the center of the main waiting room. There will be a general ticket office, waiting rooms, lunch counter, smoking rooms, barber shop, etc., on the platform floor.

The baggage room and building, 36x175 ft., and two stories high, will be on Third street, west of the main waiting room. This will be arranged so that the baggage room floor will be on a level with the car floor, and the 30 foot road so graded on the street front that baggage wagons can load directly from the baggage room without elevators.

An incoming baggage room will be provided on Central avenue, approached by the rotunda before mentioned. It will be otherwise similar to the main baggage room. The platforms will be about 700 feet long under the viaduct of Smith street. To accommodate this arrangement it will be necessary to vacate John street, North Pearl street, and the intersecting alleys.

This vacation has been approved by the Board of Public Works and the Board of Aldermen, and is now pending before the Council, where no opposition is expected.

The car sheds cover ten tracks, with sufficient platforms to accommodate five roads with two tracks each, being much more commodious than the Grand Central in New York city.

The style of the building is to be Eastlake and modern Gothic, treated with Queen Anne features. This will be relieved by bold projections, giving a picturesque outline and a very attractive and impressive façade, quite dissimilar to any depot in this country. Its material will be stone in the first or platform story, and red pressed brick above, with light colored stone trimmings and red terra cotta ornaments interspersed to relieve the plain surfaces.

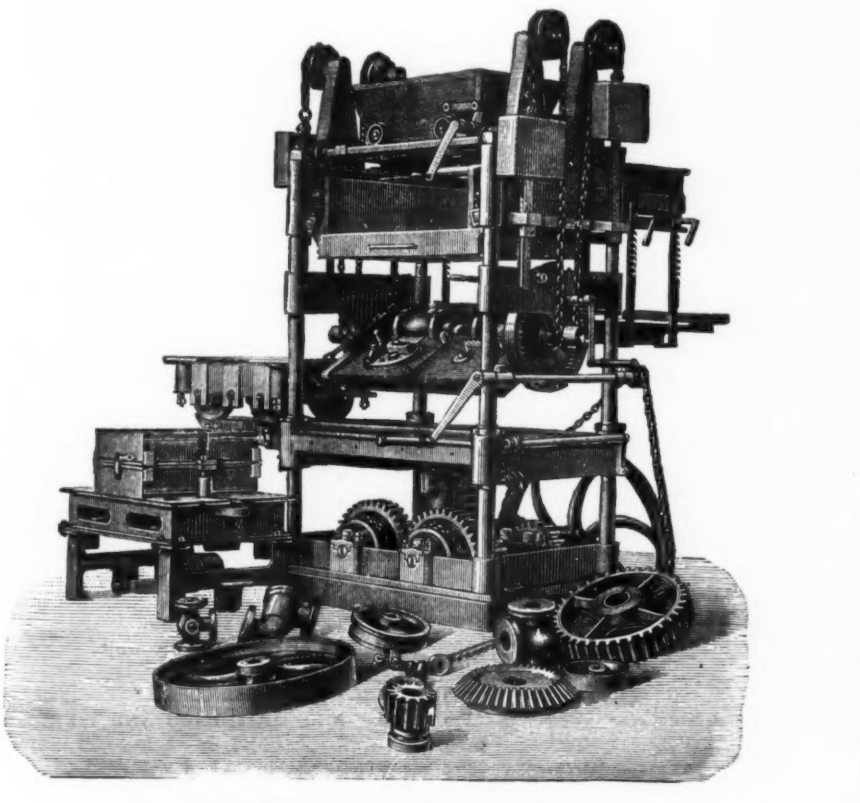
The building itself will cost about $400,000. The entire cost of ground, track, and buildings will be about $1,000,000.

The railroad immediately in charge of the enterprise is the Cincinnati, Indianapolis, St. Louis and Chicago Railway Company, with M. E. Ingalls, Esq., president, at the head of the enterprise. W. W. Boyington, Esq., of Chicago, is the architect of the building. Work will be commenced as soon as the streets and alleys are vacated.—*Railway Review.*

THE PIUTE CENSUS.—The statistics of the Nevada Indians were collected by Indian enumerators. A circle on the paper represented a wigwam or a camp. Within each circle the enumerator placed figures to represent the number of persons counted, squaws and children being represented by different signs. This method, though rude, has served to furnish an accurate census of the Piutes.

IMPROVED MOULDING MACHINE.

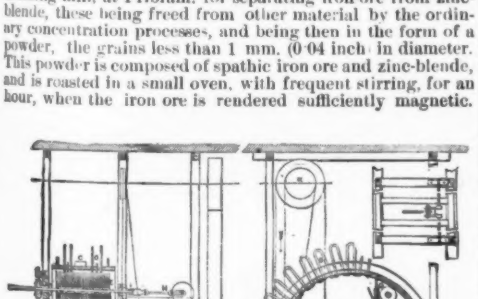
THE moulding machine shown in the annexed cut was exhibited at the Patent Exhibition at Frankfort-on-the-Main, by the constructors and patentees, P. Gallas and Aufderbeide, of Kaiserslautern, Germany. Moulding machines, as generally constructed, could only be used for very thin or flat objects, but the Gallas and Aufderbeide machine can be used for objects up to 24 inches in thickness and for complicated models, such as pump barrels, valve boxes, etc. The moulding in the nowel and in the cape takes place at the same time, and the entire operation is completed in five minutes. Objects without cores can be moulded by any inexperienced laborer. The models can be pressed into the sand with very little power, and the mechanisms for turning, raising, and lowering the forms are very simple in construction and can be manipulated very easily. The sand sieve at the top of the machine is a very ingenious device, and is so constructed that a quarter of a revolution of the crank from right to left is all that is required to operate it. The apparatus for centering the nowel and the cape is very simple, and by depressing a treadle or foot lever the parts are brought together and are locked by an automatic wedging device.



IMPROVED MOULDING MACHINE.

THE MAGNETIC SEPARATING MACHINE AT PRIBRAM.*

THE accompanying engravings show a magnetic separating machine, of which two are in operation at the Lill ore dressing mill, at Pribram, for separating iron-ore from zinc-blende, these being freed from other material by the ordinary concentration processes, and being then in the form of a powder, the grains less than 1 mm. (0·04 inch) in diameter. This powder is composed of spathic iron ore and zinc-blende, and is roasted in a small oven, with frequent stirring, for an hour, when the iron ore is rendered sufficiently magnetic.



MAGNETIC SEPARATING MACHINE.

It is then placed in the hopper of the machine, which is shaken by a cam, A, keyed to an iron shaft, and moved by belting and pulleys. The ore falls from the mouth of this hopper into a hollow cylinder of wood, with open ends, around the circumference of which horseshoe magnets, B, are set into the wood, so that their poles project about 10 mm. (0·39 inch) into the inside of the drum or wooden cylinder. Outside the drum, and 40 cm. (15·75 inches) apart, pieces of hard wood, C, are nailed. They are triangular in section, and, by the revolution of the drum, raise a stiff and elastic wooden spring, D, 1 meter (3·28 feet) long, 6 cm. (2·36 inches) wide, and 3 cm. (1·18 inches) thick at the base, coming to an edge at the apex.

When the triangular cam releases the wooden spring, the latter strikes the drum a sharp, quick blow, sufficient to knock off any particles of zinc-blende that may have attached themselves to the magnets or the inside periphery of the drum, and partially jarring off the particles of iron ore that are attached to the magnets in the portion of the drum that is uppermost and close to the elastic stick, but not the more strongly magnetic pieces of ore. The iron ore that reaches the upper portion of the drum and is then jarred off falls on a sheet iron shute, N, and the strongly magnetic particles are now swept off the magnets into the sheet iron by means of a revolving brush, E, aided by the jarring of the wooden spring, and run through a shute into the receptacle, F. The brush is provided with stiff bristles, and has two motions, one a revolution on its axis given by a screw and pinion, G, and the other a back and forward motion, produced by a crank, H, operated by a pulley and belting on the other side of the drum. Within the axle of the brush, which consists of a piece of gas pipe, is a ball and socket joint I, which permits this double motion. The large wooden cylinder has a narrow iron band running around its edge on both sides, which fits into four small grooved wheels, J, on which the drum rests; two of these wheels are connected by a shaft, and the other two are disconnected from the first two and from each other. Motion is communicated to the first-mentioned grooved wheels by a belt-pulley, R, on the same shaft, while the latter two merely support the drum and turn with it. A small pulley on the same shaft as the connected grooved wheels gives motion by means of a cord belting to a horizontal pulley, L, at the base of the upright shaft, M, on which the screw, G, is cut, which turns the pinion keyed to the axle of the brush. On the other side of the drum is a pulley which turns the shaft on which the cam belonging to the hopper is placed, and communicates motion by means of a belt and small pulleys to another shaft, which, near the middle, is bent into a crank, and gives the backward and forward motion to the revolving brush. In one machine small horseshoe magnets, to the number of 521, are used. These are the ordinary-sized magnets which are sold as toys in the philosophical instrument shops, and are 8 cm. (3·15 inches) long, 1·5 cm. (0·59 inch) wide, and made of 3 mm. (0·12 inch) plate. The other machine has 150 very large horseshoe magnets, 20 cm (7·87 inches) long, 3 cm. (1·18 inches) wide, and made of 6 mm. (0·24 inch) plate; in addition there are 104 small ones. The feed is quite slow, and, to obtain the best work, the machines must not make more than five revolutions a minute. Each machine separates four cubic feet of iron ore from the zinc-blende in a day of twelve hours. They have been thirteen months in use, and are very well liked, the preference being given to the one working with small magnets, as the large ones make the machine very heavy, so that it does not run smoothly. The separated zinc-blende falls to the bottom of the drum, and, by the slow revolutions, gradually works toward the sides where it falls into troughs prepared for its reception. The first operation is to separate the original powder into an iron ore containing some blende, and a blende containing some iron. These are each reworked separately, and the division is then considered complete.

* From a paper on Ore-Dressing and Smelting at Pribram, Bohemia, read by Ellis Clark, Jr., of Philadelphia, before the American Institute of Mining Engineers, at the Philadelphia Meeting, February, 1881.

THE POPULATION OF PRUSSIA.—By a recent census, the population of Prussia is set down as 27,278,395 souls, of whom 1,122,440 live in Berlin. Eastern Prussia has 1,933,936; Western Prussia, 1,405,898; Brandenburgh, 3,398,091; Pomerania, 1,540,034; Posen, 1,703,397; Silesia, 4,007,473; Saxe, 2,313,007; Schleswig-Holstein, 1,127,149; Hanover, 2,120,168; Westphalia, 2,043,242; Hesse-Nassau, 1,554,376; Rhine Prussia, 4,074,100; and Hohenzollern, 67,534. Among the Governmental districts, Munster has 470,544; Wiesbaden, 731,425; Coblentz, 604,052; Dusseldorf, 1,591,369; Cologne, 703,937; and Aix-la-Chapelle, 525,697.

BRICK-AND-CONCRETE AND CONCRETE GASHOLDER TANKS.

By Mr. W. H. EDINGER, Stud. Inst. C. E.

[A paper read and discussed at a meeting of the Students of the Institution of Civil Engineers, on May 6, and to which has since been awarded a Miller Prize.]*

IN "The Theory and Practice of Gas Lighting," by Mr. T. S. Peckston, published in 1819 (page 220), a gasholder is described as "composed of two distinct parts—that is to say, a capacious inner vessel, in large works generally made of sheet iron, which is closed at the top and open at the bottom; and a cast-iron tank or wooden vat of about 1 foot or 18 inches greater diameter, for containing water." It is one of the earliest works upon gas lighting, and this extract affords an idea of the materials from which gasholder tanks were constructed in the early years of this important industry.

Wooden vats, such as are used by brewers, were little employed, but tanks of cast iron were extensively adopted for some years, being constructed of flanged plates bolted together, and calked at the joints with iron cement. The tank was then encircled on its exterior by wrought-iron hoops, as a support against the pressure of the water it contained. This type of tank is only now constructed where the site is of such a nature as not readily to admit of the use of any other material, especially in the presence of large quantities of water. Wrought-iron plates have also been used in the construction of tanks, and stone has been employed where bricks could not be easily obtained, especially on the Continent; but brick has been perhaps more extensively adopted than any other material.

Lime-mortar, hydraulic lime, and Roman cement have been gradually superseded by Portland cement, which was employed, first in the foundations, and then in the joints and rendering of brick tanks, till finally, in 18 1, Mr. G. T. Livesey, M. Inst. C. E., constructed a tank of Portland cement concrete, faced or lined with a thin brick wall, and known as a "composite" tank. The present paper treats of this method of building, and that which immediately followed it—of using concrete alone.

The nature of the site of course to some extent determines which of the two modes of construction is applicable. Trial borings are therefore usually made to ascertain the character of the subsoil; the London clay, as it is impermeable to water, being no doubt the best for the purpose.

The ordinary manner of commencing the construction of a tank is to excavate an annular trench to the depth of the foundations, and wider than the intended wall, the sides being shored. A trammel or beam compass of wood or iron, of a length equal to the radius of the intended tank wall, and having a lead plumb-weight suspended from its end at the required distance, is placed in the center, so that a circle is insured while building the wall. On its completion the earth in the interior of the tank is removed with the exception of that forming the dumpling—generally a truncated cone, this shape having the greatest strength—and the surface covered with a layer of some impervious material, to prevent leakage.

Brick-and-concrete tanks have been occasionally constructed by building up an inner and an outer face of brick work, the annular space being filled with concrete; but this method, being costly, was soon rejected, the inner brick facing only being retained, and the back of the concrete wall being shaped by moulds.

A tank designed by Mr. V. Wyatt, the constructing engineer to the Gaslight and Coke Company, and erected at the Redheugh works of the Newcastle and Gateshead Gas Company, has an internal diameter of 152 feet, and is 31 feet 9 inches deep from the floor of the tank to the under side of the wall coping. The wall is formed of a facing of bricks 9 inches thick, laid old English bond, and set in Portland cement mortar, the backing being of concrete composed of 7 parts of gravel to 1 part of Portland cement measured dry, which was deposited in layers 9 inches thick, three layers only being executed each day. The top was then leveled off and grouted. The brick face is not bonded to this backing, the cohesion to the bricks of the cement in the concrete being greater than the strength of a brick, thus rendering it unnecessary. The wall has brick footings, 8 feet 6½ inches wide by 2 feet 6 inches deep, and, including the concrete backing, is 3 feet 4½ inches thick for the first 14 feet of its height, measured from the top of the footings, then 3 feet thick for 8 feet 6 inches, and 2 feet 8 inches thick thence to the lower side of the stone coping. The gasholder standards are supported by sixteen piers 29 feet 10¼ inches apart from center to center, measuring from the inner side of the tank, formed of two 9 inch brick walls 4 feet 6 inches apart, and carried 8 feet back from the tank facing. The three-sided spaces thus formed are then filled with concrete, into which the holding down plates and bolts are built. An advantage claimed for this method of construction is, that the chances of unequal settlement of the concrete, and consequent fracture of the wall, are reduced. Hoop-iron bands 1-12th inch thick and 1¼ inches wide are carried through the wall and piers; they are 4 feet 6 inches apart in the height of the wall, one strip being inserted in each half-brick thickness of its width, and they form a series of concentric bands, with extra strips intersecting them at the piers. Previous to being built in they were well tarred and sanded. These bonds have not been extensively adopted, it being sometimes considered that they would afford little support to a concrete wall when the strains were sufficient to fracture the wall itself; that the insertion of such bonding is not in accordance with the homogeneous nature of concrete, and that there is no unity of expansion between it and iron; and that if used at all they would be better placed on the outside of the wall than built within it. The designer of this tank, on the other hand, contends that they strengthen it considerably, and that no fracture to which concrete walls are subject has occurred in any one of twenty tanks constructed by him in which this bonding has been used.

The clay puddle employed was well worked, then passed through a steam pug-mill, and afterward thrown into position in 9-inch layers, being well punned and trodden up to the back of the wall. Each layer was also chopped into the preceding one.

Opposite each pier two stones are placed upon the floor of the tank, to receive the holder when down, and three are built into the wall-face above these landing stones, 10 feet 2 inches apart in a vertical line, for the reception of the guide-bars. The whole of the wall has a stone coping, and a stone cap is placed upon the piers.

The inlet and outlet pipes, which are 30 inches in diameter, of wrought and cast iron, pass into a brick dry well, 11 feet in

* This paper appears in part III. of the Minutes of Proceedings of the Institution for the Session 1880-81; and is reproduced by permission of the Council, to whom also we are indebted for the illustrations which accompany it.—*Ed. Journal of Gas Lighting.*

diameter inside, and 40 feet deep to the floor, which is 2 feet 8 inches thick, and has an invert formed within it. The space between the tank-wall and the well is filled with puddle. An arched chamber, leading from the tank to the lower portion of the well, is 9 feet wide, 5 feet high, and 14 feet 1¼ inches long, from the internal face of the tank-wall to the inside of the well. The arch of this chamber is of four rings of brickwork, and the invert of three rings, the side-walls being 3 feet thick. In a previously constructed tank of this type the arched chamber was carried right through from the well to the tank, the break being adopted as more conducive to water-tightness, enabling the puddle to be well rammed down to the pipes. It also surrounds the opinion that in an ordinary composite tank, such as the one just described, and the face of which is not rendered, the water in the tank, when filled, passes through the brick work and concrete, and is arrested by the puddle backing, which receives the greater part of the hydraulic pressure, the service of the wall being to support the thrust of the puddle and earth while the vessel contains no water. The tank is 194 feet 8 inches in diameter, and 37 feet deep from the floor to the top of the coping, and is designed with a view more effectually to meet these conditions, so that, contrary to the usual practice, the counterforts or piers are placed inside the tank with brick arches connecting them, and the front of the wall thus appears as a series of panels, whose inner faces jecting piers. The puddle can thus press uniformly, and there is less chance of its shifting its place. There is no dry well, but the inlet and outlet pipes are embedded in a solid block of concrete (as in Fig. 3). The pipes are of wrought iron, 48 inches in diameter, and, in this case, are placed for convenience on opposite sides of the tank. Their great diameter allows a man to descend them to effect repairs, or to remove any deposit of naphthaline which may take place. Some engineers prefer the dry well for all tanks, but the name is apt to be a misnomer, as frequently they are full of water, which has probably leaked in at the point in the tank wall where the pipes pass through, which is the weakest portion of the structure. An estimated saving in expense of

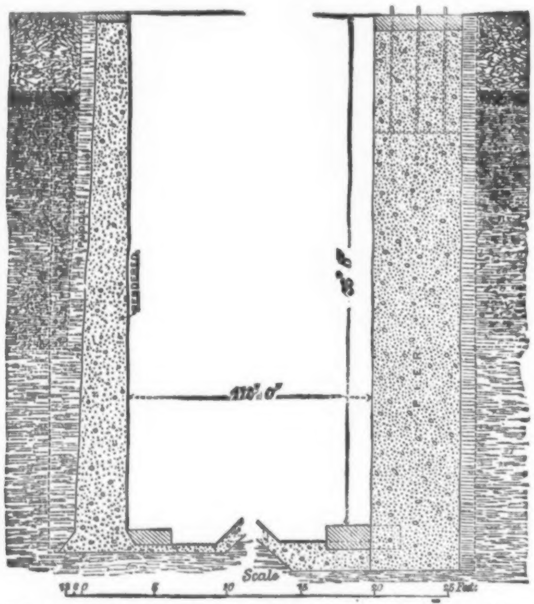


FIG. 1.—SECTIONS OF WALLS OF CONCRETE TANK.

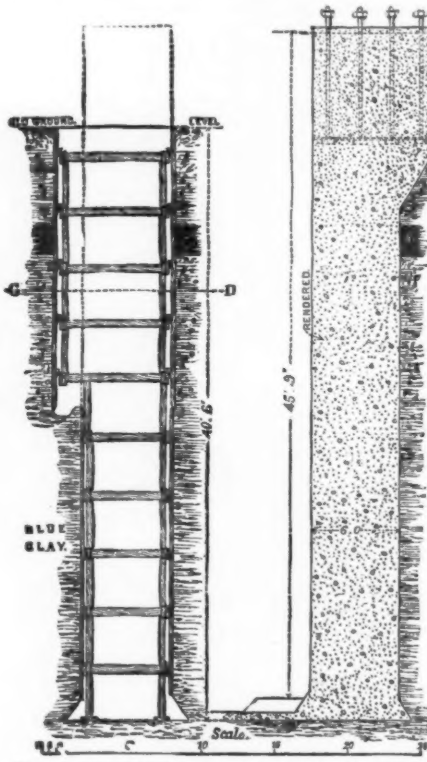


FIG. 4.—SECTIONS OF TRENCH AND PIER.

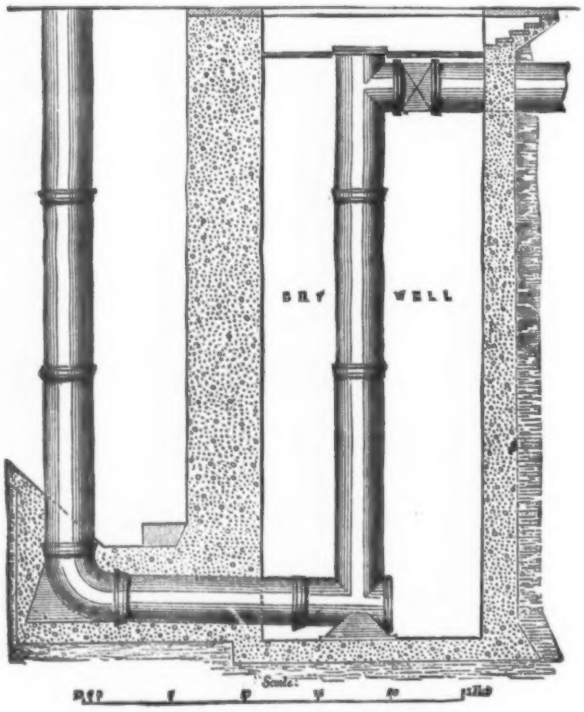


FIG. 2.—SECTION AT DRY WELL.

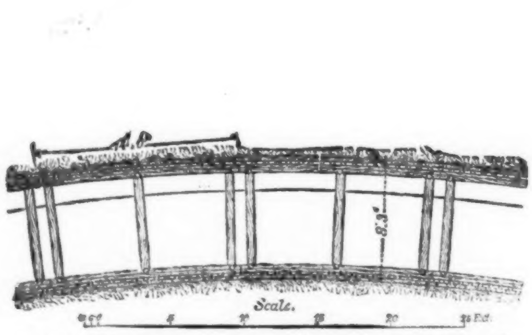


FIG. 5.—SECTION OF TIMBERING OF TRENCH AT C, D (FIG. 4).

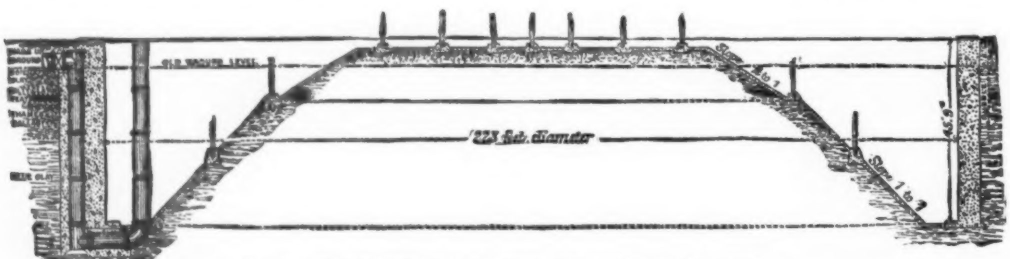


FIG. 3.—TRANSVERSE SECTION OF CONCRETE TANK

BRICK-AND-CONCRETE AND CONCRETE GAS-HOLDER TANKS

them in the chamber; a 4½ inch brick wall being built in its end to admit of the ramming of the puddle.

The cone commences 7 feet from the face of the wall, and has a slope of 2 to 1 for a distance of 40 feet, the summit being at the level of the original surface of the ground, which was 12 feet 6 inches below the top of the wall coping. The whole of the surface was coated with concrete to a thickness of 12 inches, and rendered on its surface with Portland cement. A circular brick pier, 17 feet 3 inches high, was placed on the center to receive the gas-holder framing.

In a brick-and-concrete tank, which has been constructed at the Beckton works, but of a different type to that last mentioned, the same engineer was influenced by have a batter outwards of 1 in 20. Four courses of tiles in Portland cement mortar form the base of the wall foundations, upon which a bed of concrete 2 feet 6 inches thick is raised. At its base the wall is 4 feet 3 inches wide, and at the top, 2 feet 6 inches wide, and consists of a 9-inch brick facing, with a concrete backing composed of 7 parts of gravel to 1 part of Portland cement. The standard piers are 6 feet wide, formed of brick on three sides, the space being filled with concrete. The secondary piers are of solid brickwork 2 feet 3 inches wide. They are vertical on the face of the tank, and being placed on its inside, the surface of the back of the wall is in one continuous sweep on plan, and is also vertical, so that there are no irregularities from pro- £2,000 in this case was effected by the abolition of the dry well. The cost of the tank at Beckton (where the puddle was 7s. per cubic yard) was £14 10s. per 1,000 cubic feet of tank capacity, the vessel being considered, for the purposes of calculation, flat on the bottom.

COMPOSITION OF THE CONCRETE.

A rectangular brick-and-concrete tank, recently constructed at the same works, for holding ammoniacal liquor and tar, is about 525 feet long, 60 feet wide, and 20 feet deep. As in this case it was important that the tank should be water-tight, and Mr. Wyatt, the designer, was of opinion that concrete of the ordinary working proportions could not be made so,

he adopted a somewhat different mode of construction. The wall consists of brickwork 9 inches thick for the facing and a concrete backing, but between the two materials there is a grouting of Portland cement 4½ inches thick, which renders the tank completely water-tight. In constructing such a wall, the concrete and brickwork are carried up simultaneously, a chase being preserved between the two by means of wooden filling. When the wall is raised to a height of 2 feet 6 inches, this filling is removed and the grout run in, occupying the chase and all interstices at the back of the brickwork, thus forming a complete water-tight lining between the brickwork and the concrete. Each layer is swept and watered previous to the next being run in. The grout is composed of 2 parts of silver sand to 1 part of Portland cement.

In addition to making the tank water-tight, this grout gives great additional strength, as a 3-foot length, supported at both ends, will carry a weight twice as great as York paving treated in the same manner. The test for the cement is that adopted by the German cement users—*i. e.*, the cement selected is that which stands the greatest tensile strain, when mixed with 3 parts of sand, after having set 28 days, 1 day in air and 27 days in water. Hoop-iron bonding is used as in the previously described tanks, excepting that it is not carried entirely through the concrete and brickwork, as it would otherwise interfere with the continuity of the grout. Upon the floor and cone, or dumpling, the grout is floated on in three layers each 1½ inches thick.

The tar and liquor tank was ready for use in nine months' time from its commencement, whereas, had it been built in the ordinary manner with puddle, it would not have been ready for two years.

The first tank built entirely of concrete was constructed at the South Metropolitan Gas Company's works in the old Kent Road, by Mr. Livesey, in the year 1875. Mr. John Douglas, Assoc. M. Inst. C. E., formerly of Portsea, about the same date constructed one of concrete, but with a brick lining, which was built up after the completion of the concrete wall, to insure a circular face, and, as described by him, "the only effect of which was to gratify the eye."

The method of constructing these tanks was similar to that employed in building ordinary concrete walls—*i. e.*, by the use of a framing of two shutters, of suitable length and width, placed vertically and parallel to one another, and at a distance apart equal to the width of the desired wall, being kept in their places by nutted bolts, thus forming the mould into which the concrete is placed.

A concrete tank, 172 feet in diameter, constructed by Mr. Harry E. Jones, M. Inst. C. E., at the Poplar Works of the Commercial Gas Company, is illustrated in Figs. 1 and 2. These works are situated on marsh land on the banks of the River Lea. Measuring from the surface of the marsh, trial borings showed 1 foot of soil, 3 feet of clay, 3 feet 6 inches of silty clay, and 10 feet of Thames ballast, below which was the London clay. The ground having been marked out, a trench of an outside diameter of 186 feet, and 7 feet wide, was excavated for the wall, and a further excavation was made for the dry well, both being securely timbered. Shutters for moulding the wall were made to the proper curve, were fixed in position, and the concrete dropped from a height between them. The wall is widened at its base, the width immediately above this toe being 3 feet 6 inches, tapering to 2 feet at the top. A backing of 12 inches of clay puddle was placed behind the concrete wall, commencing from the top of the London clay; the rest of the excavation was filled with clean clay. At 19 equidistant points in the circumference the wall is widened outward for the holder standards, and into the piers thus formed the holding-down bolts are built. Two stones are placed at the foot of each pier, and inserted 2 feet into it. The circular dry well is 15 feet in diameter and 43 feet deep, the wall separating it from the tank being 5 feet thick. The inlet and outlet pipes are of cast iron, 36 inches in diameter, and at the point where they pass from the well to the tank they are embedded in concrete, which at no point is less than 12 inches thick.

After the erection of the wall the earth in the center of the tank was dug out to form a truncated cone, whose summit was 22 feet above the floor of the tank, and its slope was at an angle of 45°, starting at a point 7 feet from the top of the wall. The annular floor space and the summit of the cone are coated with concrete 6 inches thick, and the slope is covered with concrete 12 inches thick.

HOW THE CONCRETE WAS MADE.

The concrete used in the work was composed of 5 parts of clean washed ballast, 2 parts of sharp sand, and 1 part of Portland cement, excepting the upper part of the tank wall, 10 feet of which, measuring from the coping downward, were formed of concrete having 1 part less ballast. The cement was required to stand a tensile strain of 330 lb. per square inch of sectional area, after having been moulded and set for 7 days under water, and had to be delivered on the ground 14 days before using, that it might be stored in a heap, so that any increase in bulk would take place then, and not after it was put into the work. The whole of the internal vertical face of the wall, 6 feet of the floor space, together with the outer side of the dry well, were rendered with Portland cement and washed sand in equal parts.

On filling this tank with water three cracks appeared, one about 12 feet long from the top of the wall, in that portion of it which was nearest to the works' boundary wall, and where the excavation had shown faulty stratification. These cracks were afterward stopped, and the tank is now perfectly sound. Its cost was £7,000, or £8 9s. per 1,000 cubic feet of tank capacity measured with the floor taken as flat. The concrete cost about 12s. 6d. per cubic yard, including the cost of moulding. The gasholder has a capacity of 1,500,000 cubic feet.

Another concrete tank, 223 feet in diameter and 45 ft. 9 in. in depth to the upper face of the landing blocks, has just been completed at the same works, from the designs of the same engineer (Figs. 3, 4, and 5). The wall was constructed in a somewhat different manner to that usually practiced.

Two concentric circles were marked out, and an annular trench 8 ft. 3 in. wide was excavated, of an outside diameter of 239 ft. 6 in.; and this trench was carried down to the London clay, which was reached at an average depth of 19 ft. The sides were timbered with runners set close (Figs. 4 and 5). Below this point the trench was narrowed to 6 ft. 3 in., which width was maintained to the bottom of the trench, and the sides were timbered with poling boards. On the top of the London clay a garland was cut to collect the water draining from the upper strata, having a slope toward a point whence a narrow cutting led to the sump. Water was met with about 5 feet below the surface of the ground, and was pumped out at an average rate of 7,000 gallons per hour.

Besides the excavation for the trench, the earth was excavated to admit the inlet and outlet pipes for a length of 18 feet and a depth of 47 ft. 6 in. from the surface of the marsh. It was further excavated at 22 equidistant points in the circumference, where the wall was corbeled outward to carry the gasholder standards; but this was not done until the concrete wall reached the point where these projections commenced. At the base the trench was beveled outward to form a toe.

No moulds or shutters being used in the trench to shape the wall, the faces of the runners and poling boards were set to a diameter of 223 feet by a plumb-line attached to the trammel. Walings 14 feet long were used, placed in pairs, with three struts in each length, and were wedged against the runners in the upper portion of the trench, to allow them to be lowered as the excavation proceeded. These frames were separated and supported by 3 foot puncheons, whose tops were nailed to the walings to prevent shifting.

The concrete for the wall consisted of 1 part of Portland cement to 8 parts of ballast. The same quality of cement was required as in the previously described tank, and the ballast was specified to contain at least one-third part of its bulk of sharp sand. The materials were mixed upon a platform and turned twice dry, and again three times after being moderately watered. The concrete was shot into place in layers 9 inches thick, not more than three layers being completed each day. When more than twenty-four hours intervened between depositing the layers, the last surface was swept and well watered before fresh material was added, which, as this was done, was leveled up to remix the constituent parts if separated by the fall from a height. As the wall was raised the timbering was removed, excepting those poling boards and runners which were against the inner face, these being left in position until the earth in the interior of the tank was taken out.

It was not specified that any clay puddle should be used, the tank face having to be rendered. The contractor for the work, however, did not think it possible to prevent the surface water coming through the wall while it was being rendered, so at his own expense he placed puddle at the back to a thickness of 2 ft. 3 in., commencing on the top of the London clay, the trench being widened in its upper part for this purpose.

When the wall had reached the point where the piers project outwardly from it for a distance of 2 ft. 6 in., the concrete was moulded by shutters of the kind mostly adopted, but which in this case were only used when the wall rose above the level of the ground. This mode of building possesses the advantage of economy, doing away with expensive shuttering which has to be made to the proper curve. It is not practicable in this way to obtain a true circle, especially one of such a great diameter, yet in this case the total error was nowhere more than 2 inches—*i. e.*, 1 inch in and 1 inch out, and as the guide-bars against which the gasholder works were fixed to the proper radius, this slight deviation was of very little importance.

Where the wall is moulded by shutters, it is necessary that the excavation of the trench should be several feet wider than the intended wall, this extra space having, after the erection of the wall, to be filled in with loose earth. This filling, however, well rammed, can never be so secure as the original undisturbed soil.

The pressure of water in gasholder-tanks increasing as its depth, their walls are generally reduced in thickness from the base to the top, the upper portion thus having the greatest amount of loose backing. In the one now described, the whole of the lower portion of the trench is filled with concrete, which is carried to the top of the wall of the same thickness, 6 feet thoughout, and so compensates by the thickness of its upper part for the relative weakness of the backing where the ground is made up above the surface of the marsh. The tank in process of construction at the South Metropolitan Works, when visited by the students of the institution in the summer of 1880, was in some respects built in this manner, the whole of the lower part of the trench having been filled with concrete.

The wall having been completed, the earth in the interior of the tank was excavated to form the cone in the center. This has a diameter at the base of 203 feet, and it slopes upward, at an angle of 45°, to the top of the clay formation. Above the clay there is a slope of 30° to the summit. The total vertical height is 44 feet above the floor of the tank. The floor and the whole of the dumpling were covered with concrete 6 inches thick, of the same quality as that used for the wall. Concrete blocks were built upon this cone or dumpling to receive the ends of the timber framing upon which the crown of the holder rests.

The inlet and outlet pipes were of cast iron 48 inches in diameter, and were surrounded with concrete to the full extent of the excavation made to receive them, a dry well being dispensed with. Two concrete landing blocks, composed of 4 parts of ballast and 1 part of Portland cement, were placed on the floor of the tank opposite each pier. A coping was carried round the wall, of moulded blocks made in the same way, and worked to a smooth face with a composition of 2 parts of washed sand to 1 part of Portland cement. The upper angles of these blocks were rounded. The piers were also capped with blocks of the same description. The inside face of the wall, and 3 feet of the floor space next to it, were rendered with equal parts of washed sand and Portland cement put on to a thickness of not less than ¾ inch, and worked to a glazed, waterproof surface. This tank, which occupied twelve months in construction, has not yet been filled with water. Its cost was £15,000, or £8 3s. per 1,000 cubic feet of tank capacity measured with a flat bottom, and the concrete cost about 10s. 6d. per cubic yard. The gasholder will contain 3,390,000 cubic feet, being one of the largest vessels of the kind.

Although the cost of some of the tanks described has been mentioned, the figures are of little value for comparison, as the price of concrete depends so largely upon the material at hand.

CONCRETE FOR EMBANKMENTS AND DAMS.

WHERE reservoirs are desired to be made in situations which afford no clay for puddle, and nothing but loose earth and stone for the embankment, the use of concrete may be extended, in forming the bulk of an embankment or dam. Where the range of stone is extensive and massive, and is bedded, it may be more advantageously cut into blocks for setting as proper masonry. The materials of the immediate site, whatever they are, are those only which can be used with economy for the main portion of a reservoir embankment. Where these consist of stone, in any form, they may be used either by way of setting, in such blocks as can be procured, or they may be broken up for concrete and used for the bulk of the embankment. The material is heavier than earth, and less liable to slip, and for both these reasons it may be used in bulk of less magnitude, with the same degree of resistance.

Concrete may fairly be taken to weigh 120 lb. per cubic foot at the least, and much more with some kinds of stone, while 96 lb. per cubic foot is a heavy average for earth. The weights of stone of various kinds are approximately as follows, per cubic foot in the solid state, viz.: basalt, 180 lb.; granite, 166 lb.; mountain limestone, 170 lb.; clay slate, 180 lb.; trap, 170 lb.; sandstone, 144 lb. as an average, but some kinds are only 130 lb.; chalk, 160 lb. When broken up for concrete into pieces of about 4 cubic inches, the space occupied by a cubic foot of solid stone extends to about 1½ cubic feet, more or less as the pieces are moved about among each other so that the angles interlock, and the quantity of sand, or fine gravel and sand, with which the interstices may be filled, varies accordingly. The cementing substance required to combine the mass must be such as will set under water. The beds of blue-lias limestone furnish a hydrate of lime which has this property in a degree sufficient for the purpose; and so, indeed, have some parts of the Wenlock limestone and the gray chalk; but in other situations, where the cementing substance must be brought from a distance, Portland cement will be the most proper material, for the reason that the less the weight to be carried to the spot the better, and that Portland cement will bear a larger proportion of sand. River-sand, if clean, is better than pit-sand, but it is by no means safe to assume, as is sometimes done, that all river-sand is better than pit-sand, inasmuch as it often contains vegetable and animal fiber in injurious quantity, which cannot be separated from it by any ordinary or economical means. The only means of separating objectionable matter from sand to be used for mortar or concrete is washing it, and river-sand has already had, before it is procured, more washing than can be artificially given to it, and if the objectionable woody fiber, rags, wool, hair, etc., remain in it where it is procurable, they may be considered as being inseparable; and sand containing these, or any of them, in considerable quantity, is unfit for this purpose. The only way to get rid of the organic matter in river-sand would be to burn it out, but that would be a process too costly to be carried out. Pit-sand, on the contrary, is free from these, but contains too much earthy matter, which requires washing out of it. It is not always possible to do this entirely, with any degree of economy, for in many cases the quantity of clean sand left after the operation of thorough washing would be so small as not to be worth having at the price it would cost; and when neither clean river-sand nor good pit-sand is procurable, crushed sand-stone may be used; but it is not a good material for the purpose, inasmuch as that any stone which can be crushed into sand contains much earthy matter. Sand procured in this way is, of course, costly, but even then it is not of good quality, and either of the other kinds is to be preferred to it when cleansed. There is another source from which the necessary fine material for concrete may be procured. Clay may be burnt as it is dug out of the ground, at an almost small expense, and if well burnt may be crushed into a fine material resembling sand, which, although not so good a material as clean sand, is preferable to some others, inasmuch as it is absolutely clean; its fault is that it is absorbent, and, if not well burnt, too much so for use. Crushed engine-cinders form another material of similar character, and equally good if procured clean, and consisting of engine-cinders only; house-ashes are, of course, inadmissible under any circumstances.

The immediate purpose for which concrete is intended to be used seems not to be always kept in view in specifying the proportions of its several components. Where it is used as a foundation to carry weight, or more properly to distribute weight over a larger area of foundation, much sand is to be avoided, inasmuch as it weakens the coherence of the materials as a whole. It is better in this case to use the cementing substance for the purpose of the adherence of the parts of the larger material to each other, and, instead of driving them asunder by interposing sand, to bring them as close together as possible, and let each piece of the larger material be coated with its due proportion of cementing substance. If, after the larger material had been brought as nearly into contact as is practicable, the space of the remaining interstices could be known, they might with advantage be filled; but, as they could not be known, the probability is that, if filled at all, they would be overfilled, and the larger parts of the material driven asunder, so that it is probably better to avoid sand altogether. It is understood, and is to be insisted upon as a point of the very greatest importance, that the materials with which concrete is to be made must be clean; no good concrete, of any sort whatever, can be made without attention to this point.

But where concrete is intended to be used as a wall to prevent the passage of water, the interstices of the material require filling up, and it is important to know what relation of space they bear to the solid material, or to the whole mass, in order that they may be completely filled. Small angular stones lie closer together than rounded gravel-stones, if means are taken to press them together; but not so without such means. When loosely tipped in a heap, the interstices are larger with angular stones than with gravel, which, without ramming, settles itself to as great a degree of compactness as it is capable of; whereas the other material can be much compacted by ramming. Ramming clean gravel is detrimental rather than useful, inasmuch as it merely displaces the parts of the material without bringing them closer together as a whole. If the material be neither angular nor much rounded, as beach shingle, it is of intermediate character in this respect, and may be rammed with some advantage.

If the material were perfect spheres the spaces among them could be calculated exactly, thus:

The distance, A B, Fig. 1, is the diameter of a ball; A C, being half the diameter, and B C, the transverse distance apart of the rows of balls, $= \sqrt{AB^2 - AC^2}$, the longitudinal distance being the diameter of a ball. In the vertical arrangement, Fig. 2, the height, $BC = \sqrt{AB^2 - AC^2}$ as before, and the cubic space occupied by each ball is $AB \times BC^2$.

If the balls are 1 in. diameter, the distance $BC = \sqrt{1^2 - 0{\cdot}5^2} = 0{\cdot}866$ in. The vertical height is the same, and the space occupied by one ball is $1 \times (0{\cdot}866)^2 = 0{\cdot}75$ cubic inch. The solid sphere, 1 in. diameter, is 0·5236 cubic inch, leaving a space around each ball of $0{\cdot}75 - 0{\cdot}5236 = 0{\cdot}2264$ cubic inch, and the ratio of the hollow space to the whole space occupied is 0·2264 to 0·75, or 30 per cent.

If the balls are 2 in. diameter, the distance apart of the rows of balls is $\sqrt{2^2 - 1^2} = 1{\cdot}732$ in., both horizontally and vertically, and the space occupied by each ball is $2 \times (1{\cdot}732)^2 = 6$ cubic inches. The solid sphere is proportional to the cube of its diameter, or to $2^3 = 8$, and is $0{\cdot}5236 \times 8 = 4{\cdot}188$ cubic inches, and the ratio of the hollow space to the whole space

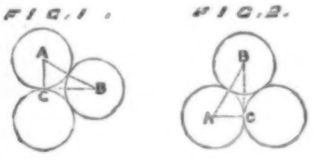
occupied is 1·812 to 6, or 30 per cent., as before. If the balls are 3 in. diameter, the percentage is the same. The distance apart of the rows is $\sqrt{3^2-(1\cdot5)^2}=2\cdot598$ in., and the space occupied by each ball is $3\times(2\cdot598)^2=20\cdot25$ cubic inches. The solid sphere is $0\cdot5236\times3^3=14\cdot137$ cubic inches, leaving a space around each ball of $20\cdot25-14\cdot137=6\cdot113$ cubic inches, and the ratio of the hollow space to the whole space is 6·113 to 20·25, or 30 per cent.

These may be compared with some recent trials of the proportions of sand and shingle at the Portsmouth Dockyard Extension works, given by Mr. C. Colson in a paper read at the Institution of Civil Engineers in February, 1881, where 15 samples of shingle of 1 cubic foot each, from various localities—viz., from Langston Harbor, Browndown, and Portsmouth Harbor, were tried, and which showed that it required, on the average of the 15 samples from the above-named localities, 38·4 per cent. of sand to fill the interstices, or 2·630 parts of shingle to 1 of sand. There was 53·3 per cent. of sand in the material as procured and used in the dock walls and other parts of the work, or 1·875 of shingle to 1 of sand; but in the trials the quantity of sand was reduced to that which was sufficient only to fill the interstices of the shingle, with the above results. At the same time 26 trials were made of the quantity of cement required to fill the interstices of the sand for mortar, which showed a proportion of 36·4 parts of cement to 100 of sand, or 2·715 of sand to 1 of cement.

Mr. G. F. Deacon, of Liverpool, made some trials of concrete used in the foundations of roadways, given in a paper read by him at the Institution in April, 1879. The concrete consisted of 8 parts of broken stone, 6 parts of gravel, and 1 of cement, making a mass, when mixed and beaten together, of 11 parts of stone and gravel to 1 of set cement; from which it would seem, the cement being included in the 11 parts, that it required 3 parts of gravel (containing half a part of cement) to fill the interstices of the broken stone, there being in the produced mass 3 parts of gravel more than was sufficient to fill the interstices. The percentage of space of the interstices of the broken stone to the whole mass was thus 3 to 11, or 27·27 per cent.

When the quantity of sand and cement is considerably in excess of that required to fill the interstices of the larger material, as in this latter case and in the walls of the Portsmouth Dockyard Extension, it takes the form of a matrix in which are embedded the larger pieces of material, and thus becomes or resembles rubble masonry, such as is found in the old castle walls and Roman buildings, in which pieces

FIG. 1. FIG. 2.



of rough stone are embedded in a coarse mortar. This is the form which concrete walls should take which are intended to retain water in a reservoir. Concrete has not hitherto been used to form a reservoir embankment entirely, but during the last few years it has been used to protect the puddle walls of earthen embankments.

In the Appendix, No. 7, of the third Report of the Rivers Commission, in 1867, Mr Rawlinson recommended the use of concrete to protect the puddle in these words: "The cheapest material which can be safely used will be concrete, made of the best hydraulic lime, and laid thickly over the entire surface of the puddle trench. Concrete, or a thick bed of mortar, should, in fact, protect puddle from contact with rock, gravel, clay, or earth at every point."—*Building News.*

DESTRUCTIVE DISTILLATION.

By "OWEN MERRIMAN."

THAT "dividends are made in the retort house" is an oft-repeated assertion the truth of which is never disputed. For it needs no statistics to prove that, if economy is not observed in the production of the crude gas, the advantage lost cannot be regained in the subsequent processes of purification and distribution. Seeing that so much depends upon the operations conducted in the retort house, it is eminently desirable that the theory of these operations should be thoroughly understood. Chief among them is the carbonization or destructive distillation of coal.

"Destructive distillation" is the term given to the application of heat to a substance without access of air, whereby the chemical compounds or combinations of elements of which the substance is composed are broken up and new products formed. Thus coal consists of the elements carbon, hydrogen, oxygen, and nitrogen, in a state or states of combination with each other (of which nothing definite is known), together with sulphur and mineral and earthy matter forming the ash. When submitted to the action of heat in a retort, the affinity which binds together the elements in the coal is relaxed, new combinations are formed, and the products which result are evolved in the state of vapor. The nature and composition of the ultimate products are dependent upon—(*a*) the condition of the coal; (*b*) the temperature to which it is submitted; and (*c*), in a less degree, on the pressure to which the evolved vapors are subjected in the retort.

(*a*) If the coal be wet, the temperature of the retort is at once reduced by the abstraction of the heat necessary to raise the water to a state of vapor; while if the temperature be regained before all the moisture is driven from the innermost portions of the coal, this water is decomposed by contact with the outside incandescent coal and the sides of the retort, its oxygen combining with carbon to form carbonic acid, and its hydrogen being set free. The amount and condition of the sulphur present in the coal necessarily influence the amount of sulphur impurities which will be contained in the gas, and likewise with the other constituents. The amount of nitrogen determines the ammonia, and the oxygen the carbonic oxides, while the hydrocarbons are given off in greater abundance and have an increased symbolic value, according as the coal contains much hydrogen—as is strikingly exemplified in the large yield and high quality of gas and tar from cannel coal.

Again, the ash, which is always present in coal, exercises a considerable influence in determining the yield of gas, by holding down the hydrocarbons and compelling recourse to a much higher temperature than would otherwise be necessary.

Another condition which has an important bearing upon the ultimate results of its distillation is the size of the pieces and the thickness of the layer of coal in the retort. When coal is distilled in large lumps or in a thick layer, that on the outside loses its gas and becomes incandescent before the coal in the center has reached the temperature required for distillation. In consequence, when gas is evolved from this latter it must pass through an incandescent mass and be redistilled, losing its carbon and gaining in diluent gases, while any moisture is converted into hydrogen and carbonic acid, as before shown. The sulphur, too, which it may be giving off as sulphureted hydrogen, becomes, in contact with incandescent coke, bisulphide of carbon—

$$2SH_2+C=CS_2+2H_2.$$

Whereas, when the coal is previously broken into small pieces and is in a thin layer, the heat penetrates more uniformly into the mass of coal, and the process of distillation is more quickly accomplished; but with this drawback—the heat acting upon a largely increased surface of coal, a greater abundance of vapors is immediately disengaged, requiring a considerable reserve of heat in the retort and furnace at the commencement of the charge to convert these vapors into permanent gas, otherwise a large proportion of liquid hydrocarbons will result.

(*b*) As we are ignorant of the manner in which the elements are combined in the coal, so are we in ignorance of the precise nature of the change which takes place on applying heat for the pur pose of its destructive distillation. Whether this consists in the simple rearrangement of the elements to form new compounds or in the decomposition of definite formations already existing in the coal into less complex bodies is not certainly known, although observed facts seem to favor the latter hypothesis. Certain it is that the first result of the process is the production of complex hydrocarbons, which, undergoing a series of decompositions through a regular descending scale of gradations, would, if submitted to a sufficiently high temperature, result in their ultimate reduction to simple gases and elementary bodies. Were this the only effect produced it would be quite possible, by a regulation of the temperature, to cut short these decompositions at any required stage, and so to produce compounds of constant and uniform composition. But the reactions in the retort are far more complicated. Besides breaking up complex hydrocarbons into more simple ones, heat has the property of building up these same compounds by accretions of bodies possessing the same constituents in lesser density.

Thus, at the temperature of the electric arc, carbon and hydrogen unite to form acetylene, and oxygen and hydrogen to form water, and from these two bodies it is possible to build up nearly the whole series of hydrocarbon compounds. This synthetical action of heat in the process of distillation is known by the term "cumulative resolution." By its influence in conjunction with that of decomposition before described the great diversity of products formed during the distillation of coal is readily explained.

As examples of its operation take the following:

At a low temperature three molecules of acetylene unite to form benzene (the benzene being decomposed into acetylene again by a strong heat)—

$$\underset{\text{Acetylene.}}{3C_2H_2} = \underset{\text{Benzene}}{C_6H_6}$$

When acetylene is heated with hydrogen ethylene is produced, and with ethylene crotonylene—

$$\underset{\text{Acetylene}}{C_2H_2} + H_2 = \underset{\text{Ethylene.}}{C_2H_4}$$

$$\underset{\text{Acetylene.}}{C_2H_2} + \underset{\text{Ethylene.}}{C_2H_4} = \underset{\text{Crotonylene.}}{C_4H_6}$$

At a red heat benzene and ethylene combine to form naphthalene, and naphthalene and acetylene to form anthracene, hydrogen being evolved in both instances—

$$\underset{\text{Benzene.}}{C_6H_6} + \underset{\text{Ethylene.}}{2C_2H_4} = \underset{\text{Naphthalene.}}{C_{10}H_8} + 3H_2$$

$$\underset{\text{Naphthalene.}}{C_{10}H_8} + \underset{\text{Acetylene.}}{2C_2H_2} = \underset{\text{Anthracene.}}{C_{14}H_{10}} + H_2$$

The consideration of these few instances will serve to explain why it is that while, with high heats, much hydrogen and other gases of low illuminating power are produced with very little benzene, they are always accompanied by a considerable proportion of naphthalene and other heavy hydrocarbons.

Not only the composition of the illuminants varies with the temperature at which the coal is distilled, but that of the other components of crude coal gas known as impurities. Thus, at a low temperature nearly the whole of the oxygen present in the coal passes off, combined with hydrogen, as water; whereas, at a high temperature, it is evolved, in combination with carbon, as carbonic acid or oxide. Sulphur usually exists in coal, combined with iron in the form of bisulphide of iron. When submitted to a moderate temperature, one equivalent of sulphur is liberated, which, taking up hydrogen, is evolved as sulphureted hydrogen—

$$\underset{\text{Ferric sulphide.}}{FeS_2} + H_2 = \underset{\text{Ferrous sulphide.}}{FeS} + SH_2$$

This reaction probably goes on continuously from an early period of distillation. When the sulphureted hydrogen comes in contact with incandescent carbon, either existing on the sides of the retort or in the coal itself, it is converted into bisulphide of carbon, with evolution of hydrogen.

From this it would appear that the popular opinion which regards the production of this compound as taking place during the last stages of distillation is in the main correct, because at this period the coal, having been nearly exhausted of its gas, and having attained to a high temperature, presents a mass of incandescent carbon, over and through which the sulphureted hydrogen and any other vapors being evolved must pass. It is, however, probable that the deposited carbon on the sides of the retort affords the requisite conditions for its formation, to some extent at least, during the whole process.

With regard to the production of ammonia little is known. The most reasonable supposition is that it results from the decomposition of some compound of nitrogen existing in the coal, but whether its production is favored by one temperature rather than another, or whether it is continuously produced throughout the whole period of distillation, is a matter involved in doubt, and which calls for thorough investigation by intelligent research.

(*c*) The influence of pressure is chiefly important by reason of its tendency to prolong the stay of the vapors which are being evolved from the coal in the highly heated retort, and so to increase their liability to decomposition. For it is evident that, if an obstruction to the exit of these vapors be formed by means of an increased pressure, they must be subjected to further heat until their tension is raised sufficiently to enable them to overcome the obstacle. The deteriorating effect upon the gas thus induced is strikingly shown by the deposits of carbon which are formed by the decomposition of hydrocarbon vapors in contact with the intensely heated surface of the retort. This action is aggravated by the mode in which the pressure is obtained or transmitted—the pulsatory motion of the gas passing through the liquid in the hydraulic main producing a backward and forward movement of the gas in the retort, involving constant friction against its surface.

There is one compound, however, which may with advantage be suffered to endure prolonged stay in the retort. This is carbonic acid, which, by contact with incandescent carbon, is converted into carbonic oxide, taking up carbon as follows:

$$CO_2+C=2CO.$$

By relieving the retort of pressure the process of fractional distillation is facilitated. Fractional distillation is the method of separating different substances in a mixture undergoing distillation, by taking advantage of the fact that they boil and pass over at different temperatures. According to Wanklyn, "The quantity of each ingredient which distills will be found by multiplying its tension at the boiling point of the mixture by its vapor density."

By this law we are enabled to account for the difficulty which is experienced in separating the light from the heavy vapors of one homologous series of hydrocarbons, because while the tension decreases with each increment of CH_2, the density is correspondingly increased. By reducing the pressure on the retort, the difference between the tensions of the various vapors is increased, and the separation of the lighter ones is proportionately facilitated, leaving the heavier compounds longer subjected to the heat of the retort.

Such are some of the reactions involved in the destructive distillation of coal. Complicated and obscure they may ofttimes be, but they act in obedience to unerring laws which, if we rightly understand, we shall be enabled to carry out the operations of the retort house with more intelligent satisfaction, as well as with greater certainty of success.—*Journal of Gas Lighting.*

PREPARATION OF NEUTRAL OXALATE OF POTASSIUM.*

By E. B. SHUTTLEWORTH.

THE rapid dry-plate processes in photography, which are at present exciting considerable attention among the more advanced classes of those engaged in the art, have created a demand for neutral potassium oxalate that cannot be supplied through the ordinary trade channels. The writer has frequently been asked for this salt, as doubtless have many of the readers of the *Journal*, and as the preparation is simple, involving no special apparatus, a few notes on the subject may prove opportune.

There are three oxalates of potassium known to chemists—the *neutral* salt to which this paper refers, and which contains two atoms of potassium to one molecule of acid; the *binoxalate*, the ordinary *salt of sorrel* of the drug stores, and that which is found in many plants containing one atom of potassium to one of acid; and the *quadroxalate*, a salt not frequently prepared or used, in which the proportion of potassium and acid are one to two.

The neutral salt is the only one used in photography. It crystallizes in rhombic prisms, is stable in the air, contains two molecules of water of crystallization which may be driven off by heat, and is soluble in about three times its weight of cold water.

It is evident that the easiest mode of preparing this salt is by neutralizing a solution of carbonate of potassium by oxalic acid. Some have recommended that the ordinary salt of sorrel, *sal acetosella*, be rendered neutral by the addition of the carbonate, but this is certainly a roundabout and expensive plan, not only as involving the use of more costly material, but unnecessary evaporation. The most expeditious method will be found to be as follows:

Dissolve a quantity—say one pound—of carbonate of potassium in an equal weight of cold water, decanting the clear solution from any undissolved sediment, if such should remain. This residue consists of potassium sulphate or silicate, and is commonly present in the ordinary salts of tartar of commerce. Put the clear solution in an enameled iron, procelain, or Wedgwood dish, add a quantity of water equal to that first employed, and heat to the boiling point. Add carefully, and by small portions, avoiding mishap by effervescence, sufficient powdered oxalic acid to neutralize the carbonate, testing carefully toward the close with test paper. If necessary filter the solution while hot and set aside to crystallize. A fresh crop of crystals may, of course, be obtained by evaporating the mother liquor.

The quantity of oxalic acid required cannot be definitely stated, as both acid and carbonate are generally impure; but theoretically, 174 parts of carbonate should require 90 of acid, and produce 202 of neutral oxalate. The product will practically be always considerably less than this, seldom equaling more than the weight of the carbonate employed.

As has been stated, the neutral oxalate is soluble in about three times its weight of water, and as photographers use a saturated solution, there is no reason, if time be an object, why a liquor should not be prepared extemporaneously, or at least that the operation of crystallization might not be omitted.

I have found that the specific gravity of such a solution is, at ordinary temperatures, 1·220, and that ten ounces of the salt, when dissolved, measure twenty-six fluid ounces. Such a solution, except made with distilled water, will, of course, require filtering, as the lime present in ordinary water is precipitated as oxalate.

DETERMINATION OF POTASSIUM.

By L. L. DE KONINCK.

THE potassium is thrown down, with the ordinary precautions, by platinum chloride; the K_2PtCl_6 is collected on a filter, washed in alcohol, and immediately dissolved in boiling water. The solution is reduced hot by magnesium. All the chlorine of the chloro-platinate is obtained in the form of a soluble chloride and a black precipitate of reduced platinum. At the same time the magnesium decomposes the water, yielding hydrated magnesia with an escape of hydrogen. When the reduction is complete the mixture is filtered, and in the neutral solution the chlorine is determined in the usual manner with a standard solution of silver nitrate, using potassium chromate as indicator

* From the *Canadian Pharmaceutical Journal*, August, 1881.

THE PRESENT STATE OF MOUNT ETNA AND THE VALLE DEL BOVE.

I HAVE remarked with surprise that the majority of modern treatises on geology and vulcanology never exactly represent by their illustrations the aspect of Mount Etna. It has seemed to me that this arises from the difficulty which authors experience in obtaining accurate pictures of this far-off mountain, so I flatter myself that I shall have been useful to the readers of *La Nature* in sketching for them the annexed view, which represents very exactly the southern side of Etna as seen from the port of Catania, eighteen and one-half miles distant (Fig. 1). Large cities, with numerous cupolas, are stretched out at the base of Etna, and numerous villages, with long, pointed steeples, lie scattered over the lower region of the mountain. These form a vast panorama, and terminate at a confused assemblage of conical hills, which formerly were so many craters. Above these we see rising, immense and majestic, the cone of the volcano, which overtops the clouds and forms the highest point of the island.

The cultivated zone of Etna extends at present beyond 3,900 feet elevation. From this limit vegetation rapidly grows poorer, and, toward an elevation of 6,500 feet, becomes very rare. However, up to the base of the central cone, that is to say, at about 10,000 feet, the vegetable kingdom is still represented by four small plants, whose botanical names are as follows: *Robertsia taraxacoides*, *Artemisia ætnensis*, *Senecio ætnensis*, and *Tanacetum vulgare*. The slope of Etna is very slight up to an elevation of 3,200 to 4,000 feet, and in general makes an angle of only 15 to 20 degrees with the horizon; beyond this it rapidly increases, but at 9,500 feet the inclination of the ground is suddenly interrupted by a sort of plain covered with black sand. This is the *Piano del lago*. At 1,300 feet to the north of this plain rises the cone of the central crater, at the foot of which we find at present the Astronomical Observatory and the *Casa Etnea*, a small hotel designed for travelers who make the ascent of the volcano.

The mouth of the crater of Etna is at present nearly 6,000 feet in circumference, since it was enlarged by about 1,800 feet at the eruption of 1879. The interior of the crater exhibits the aspect of a large cup filled with scoriæ and lava, among which are interspersed numerous fumaroles. At the bottom of the cup, at a depth of 200 feet, there is seen the aperture of the eruptive channel, which usually has a diameter of about 650 feet.

Mount Etna is situated on a tertiary formation, and is almost entirely composed of volcanic materials. The lavas which abound on its sides are formed of dolerite, in some cases feldspathic, and in others augitic. Prof. Ricciardi, who has undertaken a long series of analyses of these lavas, has just ascertained that they all contain phosphoric acid in proportions varying from 0·80 to 3·75 per cent. This fact is the principal cause of the wonderful fertility of the soils which are formed from the disintegration of the lavas of this volcano.

On the eastern side of the mountain is found the vast depression known under the name of the *Valle del Bove*. I have visited every part of this locality, and shall therefore make special mention of it.

The Valle del Bove is a gigantic ravine, which, from a geological standpoint, is one of the most interesting spots on earth. It is, in fact, upon a ground such that the naturalist, upon observing the anatomy of Etna in its nakedness, so to speak, can obtain a clear and accurate idea of the process employed by nature in the formation of volcanic mountains.

The valley is an immense crevasse in the side of Etna, and is about six and a quarter miles long by three miles wide. Its depth at some localities is more than three thousand feet, and its sides are surrounded at the north, south, and west by high rocks, several of which exhibit characteristics of aspect that are truly admirable.

Some of these rocks are formed of a very black lava, which well imitates antique serpentine. Others exhibit a color of a dark red, due to the oxidation of ferruginous matter. Moreover, the alteration of the mass of mineral is so advanced that it exhibits a whitish color similar to that of carbonate of lime, and there are also places where the lava is of a characteristic yellow color, which has caused the rocks wherein it is found to be styled *mountains of gold*.

Along with this, the rocky chains which border the Valle del Bove present a greater interest, in that they are almost all composed of several alternating strata of lava intermingled with banks of earthy materials and traversed in all directions by numerous veins of other and more recent lavas, the origin of which can be easily explained. For it is well known that when one of the sides of the mountain bursts to give passage to the incandescent matter, there results usually around the principal fracture other radiating fractures which decrease in size as they are prolonged to varying distances; and the liquid lava then penetrates these secondary fractures, fills them, and seals them up on solidifying.

Thus, by examining the position of these strata and veins, there may be constructed a very extended chronology of the old eruptions.

The Valle del Bove must have been formerly much deeper than it is in our day. At present its bottom is filled with broad torrents of lavas which have been vomited up at recent epochs. Thus, in the middle of the upper part of the valley there is seen rising a crateriform cone, which dates from the eruption of 1811; and close to the south side are two other cones which belong to the eruption of 1852.

From the foot of these two cones there is seen to begin a lava stream, which, after inundating the valley, precipitated itself from one of its edges so as to form a cascade of fire 980 feet high by 325 feet wide. This lava, which obstructs the greater part of the bottom of the valley, shows large undulations which cause it to resemble a rolling sea that has been suddenly congealed and transformed into stone.

The Valle del Bove has become in our age a subject of serious attention on the part of several illustrious geologists, who have advanced different opinions to explain its origin. Some of these, on observing the immense quantity of materials that Etna has thrown out, even in our day, have thought that the east side of the mountain has become depressed through the effect of the vacuum that the continuity and power of the eruptions must have caused within it. Others, on observing that the strata of the edges of the valley are strongly inclined toward the exterior, have believed that they saw therein a proof of Bouch's theory of craters; and they have thence supposed that Etna being due to a violent upheaval, the ground was ruptured on the east side and was less influenced than the other sides by the force which upheaved it.

These last mentioned observations have been especially based upon the consideration that the lava being a molten substance, can not form thick layers in a vertical direction, and that consequently the strata that are observed on the borders of the Valle del Bove must at first have had a horizontal position. But, after the facts observed during the eruption of 1852, this theory is no longer tenable.

I have said that at this epoch a torrent of lava, after flowing into the Valle del Bove, precipitated itself from a height of 980 feet. Now, after the eruption it was ascertained that upon the steep declivity which gave rise to the cascade the lava formed a stratum more than 130 feet thick. Here, then, is a striking example of the formation of a stratum in a vertical direction.

This effect of the lava is easily comprehended when we reflect that the fluidity that it possesses on issuing from the ground is not entirely due to fusion, but also to the quantity of water and gas with which it became impregnated in the depths of the volcano. Apropos of this, Prof. Sylvestri says, in one of his works: "Water and fire, which ordinary people regard as elements that are incapable of finding themselves in association, may, however, through the effect of great pressure, assimilate perfectly. Now, through the effect of the immense pressure that these elements undergo at the bottom of the volcano, the water penetrates the solid bodies and brings them to a state which is neither liquid through fusion nor through solution, but to a pasty state due to the union of the physical particles that are capable of moving over one another in the half-molten material which surrounds them, mixed with water and other substances capable of keeping them separate."

Thus, as soon as the lava appears at the surface, the water and gases that it contains begin to disengage themselves in the form of clouds of vapors, and it follows that the solid molecules contract more quickly, and that the lava fixes itself sooner and more easily than it would do were its liquid state due entirely to fusion.

Of all the opinions which have been put forth to explain the origin of the Valle del Bove, the most probable one is certainly that of the illustrious Italian geologist, Stoppani. This savant explains its formation from facts recently observed in Papadayang, the largest of the volcanoes of the Island of Java, and in a volcano of the Isle of Palms (Canaries). It is known that after one of the most violent eruptive paroxysms, these two volcanoes remained ruptured, and, so to speak, gutted from their axis of eruption to the external limit of one of their sides, and there resulted from this upon the side of the volcanoes a deep and wide valley ending toward the interior in a large elliptical gulf, serving as a crater. According to Stoppani, an analogous phenomenon has taken place in Etna, where the widening of the eruptive axis is indicated by the elliptical contour of the Plain of the Lake, which was formerly the central crater of the volcano. This plain, which is now filled up, forms the base of the cone of the present crater.

Thus, then, Papadayang and the volcano of the Isle of Palms show us the past history of Etna, and the latter, in its great, filled-up crater and its small terminal cone, perhaps shows us the *future* of those two distant volcanoes.—*V. Tedeschi di Ercole.*

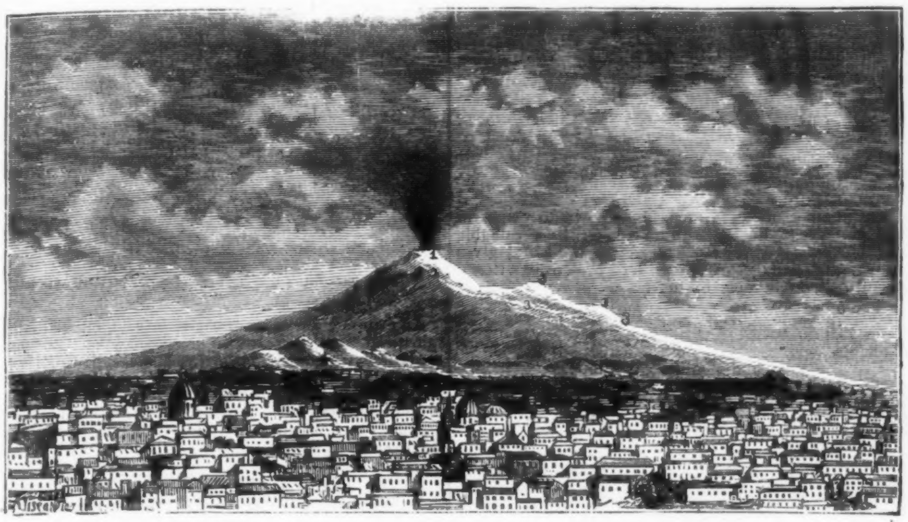


FIG. 1.—MOUNT ETNA SEEN FROM THE PORT OF CATANIA (South Side).

1. Edge of the central crater. 2. Astronomical observatory. 3, 3, 3, 3. Rocks bounding the Valle del Bove. 4. Mount Rossi. 5. Village of Nicolosi.

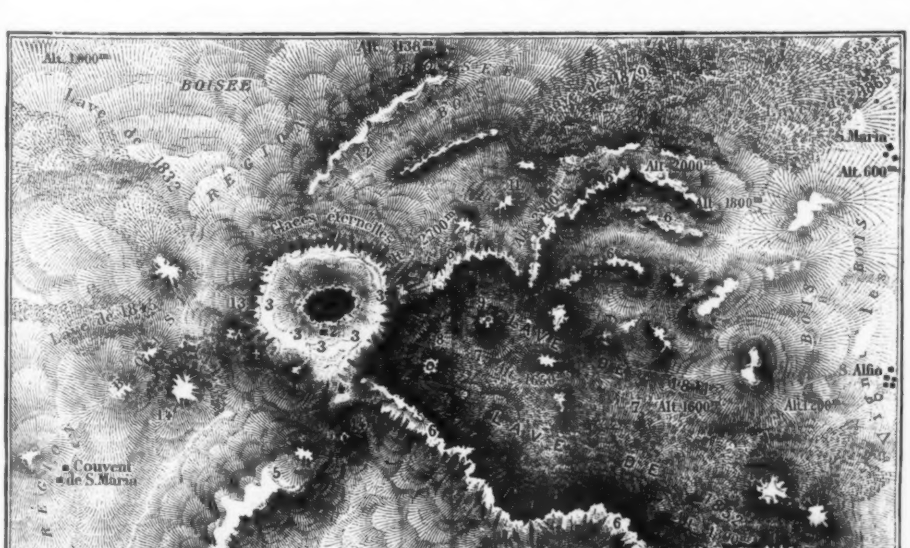


FIG. 2.—MAP OF THE UPPER REGIONS OF ETNA.

1. Central crater (16,800 feet altitude). 2. Astronomical observatory. 3. Plain of the Lake. 4. Montagnola (8,660 feet). 5. La Schiena dell'Asino. 6. Rocks bordering the Valle del Bove. 7. Valle del Bove. 8. Eruption craters of 1852. 9. Crater of 1811. 10. Monte di Calanna (4,200 feet). 11. Craters of 1879. 12. Valle del Leone. 13. Other craters of 1879. 14. Ancient craters. 15. Casa del Bosco.

EXPANSION AND CONTRACTION OF TREE TRUNKS.—Recent botanical research has shown that the trunks of trees undergo daily changes in diameter. From early morning to early afternoon there is a regular diminution till the minimum is reached, when the process is reversed, and the maximum diameter is attained at the time of twilight; then again comes a diminution, to be succeeded by an increase about dawn—an increase more marked than that in the evening. Variations in diameter are believed to coincide with the variations of tension, but they are shown to be inverse to the temperature, the maximum of the one corresponding roughly to the minimum of the other, and so on.

THE VARIETIES OF LINSEED IN ENGLISH COMMERCE.

By E. M. HOLMES, F.L.S., Curator of the Museum of the Pharmaceutical Society.

ALTHOUGH linseed has been imported into this country during the last twenty years to the value of four or five millions sterling annually, only a small proportion of this quantity is used in pharmacy in the form of seed. It is perhaps on this account that the great differences in various samples of commercial linseed have received but little attention from pharmacists, although it is true that the wholesale druggist distinguishes in the rough way between Russian and English linseed, which resemble each other in size, by plunging the hand into it, the English readily giving way beneath the finger, while the Russian offers a certain amount of resistance.

Fig. 1.—*Lolium species.*—English, etc.

Fig. 2.—*Polygonum lapathi folium*, L.

Some idea of the number of commercial varieties and of the quantities imported may be obtained by a reference to the following returns as given in the Blue Books for 1879.

		Quarters.
Russia (Northern Ports)	579,508	923,254
" (Southern Ports)	343,746	
India (Bombay and Scinde)	43,019	603,427
" (Bengal and Burmah)	560,408	
Germany		86,101
Holland		16,659
Chili		8,936
Italy		7,147
Turkey, Asiatic	2,542	4,449
" European *	1,907	
Gibraltar		33

This table may be taken as giving a fair average of the

Fig. 3.—*Spergula arvensis*, L.—Russian, etc.

amount imported during the past few years, with the following exceptions; a decrease has taken place in the importations from Bombay, Scinde, and Gibraltar. In 1875 10,073 quarters of linseed were imported from Algeria, but none appears to have been received from there since that date. On the other hand an increase has taken place in the quantity received from Southern Russia and Chili.

In Chili linseed cultivation would appear to have only been taken up during the last few years, owing to the falling off in the demand for wheat.

It has already been shown in the pages of this and other journals that irritation is sometimes produced when linseed-meal has been applied to inflamed surfaces,† and that in some cases nettle rash and inflammation of the air passages have been caused by its use. This action has been attributed

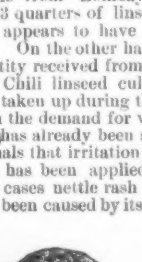


Fig. 4.—*Chenopodium album*, L.—Dutch.

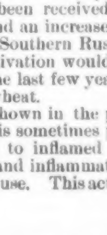


Fig. 5.—*Silene inflata*, L.—Dutch.

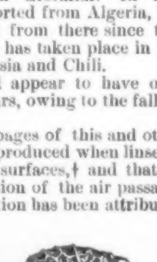


Fig. 6. Dutch.

to the presence in it of cruciferous seeds.‡ Still more recently linseed has been recommended for internal use by Dr. Sherwell, of Brooklyn, in certain skin diseases.

Although excellent papers on the microscopical characters of linseed have been published by Stoddart§ and Pocklington,* and another by Greenish,† on the means of detecting the adulterations in linseed meal, yet few chemists have the leisure to give a careful microscopic examination to every lot of linseed meal they purchase, and some experience would be required to recognize the powdered foreign seeds present in it.

It occurred to me, therefore, that a much simpler means of obtaining linseed meal free from foreign seeds would be to buy the linseed, examine it for the presence of injurious weed seeds, sift them out, and then grind the meal. American drug mills that can be worked by hand are now easily obtained, and this mode of procedure would have the additional advantage that the meal could be ground frequently, for it has been stated that the crushed seed rapidly oxidizes when long kept and acquires a degree of rancidity very injurious when the poultice made from it is applied to open wounds.

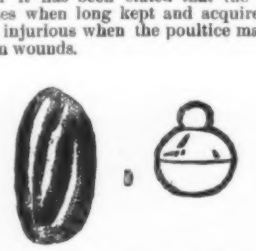


Fig. 7.—*Camelina sativa.*—Russian, etc.

A large number of weed seeds are known to occur in different varieties of linseed. Dr. Voelcker, in a valuable paper in the *Journal of the Royal Agricultural Society*‡ gives the following percentages of foreign seed present in a dozen samples of linseed examined by him:

Bombay linseed	4½	per cent.
Finest ditto	1¾	"
Black Sea seed	20	"
Second sample	19	"
Third sample	12½	"
Morshanski seed	7	"
Fine St. Petersburg	8	"
Common (Rijeff) do	41	"
Second quality	48½	"
Third quality	70	"
Medium Riga seed	35	"
Riga crushing seed	42	"
Second sample	49½	"

But it must not be supposed that weed seeds occur naturally to the extent of 49½ or 70 per cent. in linseed; the average amount would probably be about 7 or 8 per cent., or from a very foul land 20 or 30 per cent. In order to produce the best qualities of linseed, such as are sold to makers of pure linseed cake and oil crushers who are prepared to pay the proper price, the weed seeds, which are mostly smaller than linseed, are separated by sifting. These siftings are subsequently added in certain proportions to linseed to form second, third, or fourth qualities, according to the price which buyers are prepared to pay. This is said to be done after the linseed leaves the Russian ports; barges laden with the siftings being sent a little way out to sea to meet ships having linseed on board, and an amalgamation of the siftings with the linseed is effected on the high seas, so that the mixture may be described on landing it in this country as "linseed genuine as imported." Good linseed can, however, always be purchased, guaranteed not to contain more than 4 per cent. of foreign seed, by those who are willing to pay the proper price for it.

As the weed seeds found in linseed differ in their chemical composition, some, such as cruciferous seeds, yielding a non-drying oil and others a nutritious farina, such as the seeds of *Polygonaceæ*, *Spergula arvensis*, and certain leguminous seeds, it is obvious that some samples would be quite unfitted for pharmaceutical use or for making linseed oil for use in painting, and others would be fitted only for cattle food, etc.

Having occasion recently to examine some samples of linseed, I was struck by the fact that although there was great similarity in the weed seeds most abundantly found in European varieties of linseed, yet there were generally present, sometimes in small quantity only, some seeds in each commercial variety which might be regarded as distinctive of the country in which the linseed was collected, and it occurred to me that a brief description and figure of such seeds might be of use in pharmacognosy and in the arts generally, by enabling the purchaser to know what linseed he was purchasing, and what purpose it was best fitted for.

The linseeds of commerce may be roughly divided into two groups, the one consisting of seeds averaging twelve or fourteen seeds to a grain weight, and the other in which the

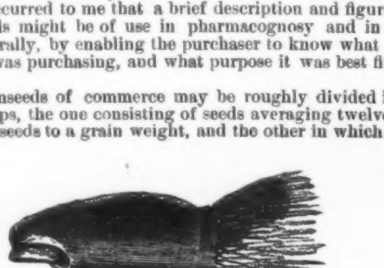


Fig. 8.—*Centaurea Cyanus*, L.—Russian.

seeds are about twice the size, so that six or seven are equal to one grain.§ To the first group belong Russian, Dutch, English, and ordinary Calcutta seed, and to the second, Bombay, "bold" Calcutta, Sicilian, and Ionian linseed. Of the Chilian, Gibraltar, and Algerian seed, I have not been able to procure specimens.

As to the difference existing in the two groups, opinions would seem to differ. According to Greenish, those which are grown in a tropical soil do not produce so fine a quality of oil, but yield a larger amount of farina, and make a more nutritious cake. Professor A. H. Church, on the other hand, who has paid much attention to linseed oil for use in oil painting, informs me that the largest and palest seeds, provided they are free from foreign seeds and dirt, yield the best oil and the largest percentage if cold drawn, and that he does not find any difference in the oils from seed grown in different climates, provided the conditions as to ripeness, size, purity, and color, are fulfilled.

Dr. Voelcker's analysis seems to bear out this statement, the difference in amount of oil obtained from seed in the north and south of Russia, and in England, being very slight, although the average percentage of nitrogen is less in the Russian than in the English seed.

Fig. 9.—*Panicum miliare*, Lam.?—South Russia.

An examination of commercial linseed will show that certain weed seeds are common to several kinds, and that such seeds cannot therefore be looked upon as distinctive of any one sort. There are, however, a few weed seeds which, being derived from plants common in one country and not in another, may be regarded as characteristic. The entire absence of a seed present in some kinds also becomes a distinguishing feature in others.

SMALL LINSEED.

English Linseed.—This kind is not, as might be supposed, produced in Ireland, for although that country produces

Fig. 10.—*Setaria species*—South Russia.

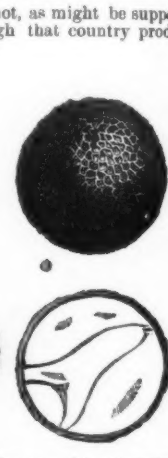


Fig. 11.—*Sinapis species.*—South Russia.

much more flax than England, the flax is usually pulled before the seed is ripe, since permitting the seed to ripen is said, at all events in the Irish climate, to injure the quality of the flax. Mr. C. Umney informs me that in England flax is grown for seed chiefly in the counties of Lincoln, Cambridge, Suffolk, Devon, and Somerset, that of the last two counties being of superior quality.

English linseed is, as a rule, remarkably free from weed seeds, has a greenish-brown hue, and easily yields to pressure under the fingers. The weed seeds found in it are principally a grass seed, Fig. 1, and that of *Polygonum persicaria*, Fig. 2, a flat, black, polished seed, somewhat

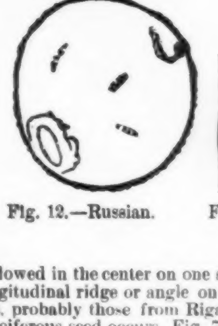


Fig. 12.—Russian.

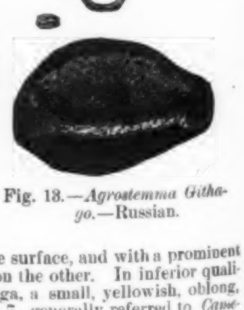


Fig. 13.—*Agrostemma Githago.*—Russian.

hollowed in the center on one surface, and with a prominent longitudinal ridge or angle on the other. In inferior qualities, probably those from Riga, a small, yellowish, oblong, cruciferous seed occurs, Fig. 7, generally referred to *Camelina sativa.* Under a lens the radicle can easily be seen to form a longitudinal ridge at the back of the cotyledons. Another seed rarely present is that of *Chenopodium glaucum*, Fig. 4. These are lens-shaped, black, and polished, but usually have a portion of their gray utricular coat attached.

Dutch Linseed.—This kind, next to the English, is the purest seed. The weed seeds found in it are almost exactly

* Exclusive of Wallachia and Moldavia.

† *Pharm. Journ.* [2], xi., p. 686; *Brit. Med. Journ.*, May 24, 1879, p. 778.

‡ *Pharm. Journ.* [3], ii., p. 212.

§ *Pharm. Journ.* [3], i., p. 663.

* *Pharm. Journ.* [3], ii., p. 701.

† *Pharm. Journ* [3], ii., p. 211.

‡ Vol. ix, p. 5.

§ These figures are taken from an average of three lots of each kind, weighed in a chemical balance by Mr. W. H. Symons. "Bold" Calcutta is intermediate (eight to nine seeds to one grain) in character.

the same as those found in the English linseed, consisting of those represented at Figs. 1, 2, and 4, but the seeds of *Chenopodium album* are found in it more abundantly. The seed represented at Fig. 5 appears to be characteristic of the Dutch linseed, at least I have not observed it in the English kind. It is flattened, circular, indented on one side, brown, and is seen under a lens to be covered with minute projecting wart-like points, somewhat concentrically arranged. Some of the seeds, probably the more mature, are of a dark gray color. Another seed, which I have not observed in the English linseed, is represented at Fig. 6.

According to Professor Bernardin, flax does not appear to be grown anywhere in Belgium for the sake of its seed alone, and for sowing purposes until recently it was only allowed to enter Belgium from Riga, Libau, and Windau in sealed tins, with certificates from the Belgian consuls, the Riga seed being considered to yield the best flax. The first crop of

Fig. 14.—Indian.

flax grown from the Riga seed yields a coarse fiber, the second crop yielding the best flax.

It is probably the seed of this second crop which is sent to this country, as it does not pay to sow the home-grown seed for flax after the second crop.

On referring to the English Blue Books it will be observed that although Dutch linseed is imported to England to the extent of about £70,000 yearly, yet England exports to Holland from £50,000 to £80,000 worth of linseed annually. The reason of this appears to be that East Indian and possibly some Black Sea linseed is purchased by Holland for crushing, it being fit for feeding purposes, while the Dutch

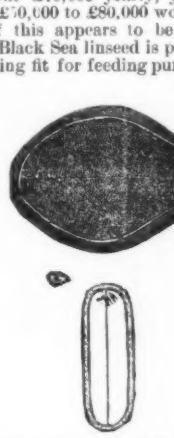


Fig. 15.—*Sesamum Indicum*.—Indian.

yields a purer oil, and is therefore sought for in England for that reason.

Baltic Linseed.—That which is known under this name in England is chiefly received at Hull, and is imported from St. Petersburg, Revel, Riga, Libau, and Windau, and Memel in Prussia, on the Russian border.

It varies much in quality and in the kind of weed seeds it contains, according to the district where it is grown.

The northern varieties, such as those grown at Archangel and Homel, are remarkable for the preponderance of the seeds of *Camelina sativa*, Fig. 7, and *Spergula arvensis*, Fig.

Fig. 16.—*Sinapis species*.—Indian.

3. The latter seed is easily recognized by the pale prominent rim which divides it into two hemispheres, and by the dull black minutely rough surface, covered more or less with buff-colored scaly-like points.

The grass seed, Fig. 1, and *Polygonum persicaria*, Fig. 2, are also of common occurrence in North Russian linseed, but are absent in that from the Baltic Sea ports. In the Lithuanian specimens that I have seen, the seed of *Centaurea cyanus*, Fig. 8, forms a prominent feature, and one specimen from Livonia might, from its purity and freedom from weed seeds, have been taken for English.

Some of the southern varieties grown at Karatschev and Orel (sometimes spelt Orlov) resemble the northern varieties in every respect except that they contain in addition the small grass seed represented at Fig. 9, which I have never observed in North Russian linseed.

Black Sea Linseed.—This kind comes chiefly from the ports of Taganrog and Odessa. It is remarkable for the entire absence of the grass seed, Fig. 1, and for the presence of the grass seed, Fig. 10, and of the spherical cruciferous seeds, Figs. 11, 12, of different sizes, but chiefly of a black or brownish color. Fig. 11 is brown and Fig. 12 is black, and not a cruciferous seed. The reticulations of the former and the raised points of the latter can only be seen under a Coddington lens.

One of the most characteristic of the weed seeds is represented at Fig. 9. This, which is the fruit of a grass, *Panicum*, is oval and convex on both sides, is remarkable for the brilliantly polished canary yellow or bright brown surface of the two paleæ which inclose it. One of these is marked with three and the other with five veins. The tri-

Fig. 17.—*Ervum species*.—Indian.

Fig. 18.—*Medicago species*.—Indian.

angular brownish seeds of *Polygonum convolvulus*, which resemble buckwheat in shape, but are smaller and of a dull black color when the husk falls off, and the seeds represented at Fig. 13 (*Agrostemma githago*), are also present in Black Sea linseed. A very characteristic seed is that of another species of grass, Fig. 10. This is of a pale green color, flat on one side and convex on the other, the flat side being wholly covered with a glume and the convex side only partially so, exposing the palea beneath it, which is seen under a lens to be covered with transverse striæ, and by this feature is easily recognized.

The Turkish linseed seems to agree in character, so far as we have observed, with the Black Sea linseed.

Calcutta Linseed.—This is remarkable for the absence of the seeds so characteristic of the European linseeds, *e. g.*, those represented in Figs. 1, 2, 3, and 7. It contains numerous globular cruciferous seeds, in which character it approaches Black Sea linseed, but these are mostly of a yellow or brown tinge and not of the prevailing black hue of those found in the South Russian varieties. The weed seeds especially characteristic of Calcutta linseed are shown at Figs. 14, 15, 16, and 17. That represented at Fig. 14, although it occurs sparingly, is very characteristic. It is triangular, of a dull black color, having two straight sides and the third one convex, but all marked with two or three deep pits. Fig. 16 is a cruciferous, pale yellow seed, globular and slightly compressed, and has the radicle folded between the cotyledons, its position being marked by a broad stripe along the edge of one side of the seed. Fig. 15 is the well known gingelly, teel, or sesame seed, *Sesamum indicum*. It is flattened, dull black, with a prominent line running along the margin, but more evident on one surface of the seed than on the other. The minute dotted markings represented in the figures are only evident under a powerful lens.

Besides the above mentioned seeds those represented at Fig. 17 are of frequent occurrence in Calcutta linseed. It is a leguminous lens-shaped seed, of a greenish color and speckled with small black dots.

Bold Calcutta Linseed is intermediate in character between the smaller and larger varieties, and contains the same weed

Fig. 19.—*Catanian*.

Fig. 20.—*Catanian*.

seeds as the ordinary Calcutta linseed, but the mustard seeds are less abundant in it.

LARGER LINSEEDS.

Bombay Linseed.—This is distinguished from the Calcutta kind by being larger and having a brighter and more polished appearance. It contains, as a rule, fewer globular cruciferous seeds, and besides the sesame seed, Fig. 15, there occur in it the small pods of a species of medicago, Fig. 18. Seeds resembling those in Fig. 10, but rather larger, also occur in it. Neither the weed seed, Fig. 14, found in Calcutta linseed, nor any European weed seeds appear to occur in Bombay linseed.

The large white* or pale yellowish linseed grown in the Nerbudda Valley is said to be remarkably free from rapeseed, and to yield two per cent. more oil than ordinary brown linseed and to give it out more freely, while the resulting cake is softer and sweeter. A specimen received from the India Museum and now in the museum of the Pharmaceutical Society fully bears out the statement as to the purity and excellent quality of the seed, and seems admirably fitted for yielding a light-colored, pure oil for use in oil painting.

Catanian linseed differs very little from the Ionian, except in containing rather more weed seeds. Two of these seem to be characteristic, and are represented at Figs. 19 and 20. The former is slightly angular, of a dark reddish brown color, and a soft outer coat, easily rubbed off between the fingers and disclosing a horny nucleus externally of a reddish color.

Fig. 17 represents a pear shaped whitish seed, with a

Fig. 21.—*Galium spurium*.—Catanian.

Fig. 22.—*Medicago species*.—Catanian.

prominent ridge on two opposite sides, but more evident at the narrower end. The surface is wrinkled, but rarely forms so regular a network as represented in the specimen figured, and the dotted surface there represented can only be seen under a good lens. Other weed seeds of somewhat frequent occurrence, but which also occur in other European linseeds, are a species of *Galium*, Fig. 21, easily recognized by the central hole on the flattened side, and a species of *Medicago*, Fig. 22, and the grass seed, Fig. 1.

Ionian Linseed.—The only sample of this kind that I have examined was remarkable for its purity and large size, and much resembled the Catanian in appearance. Two of the

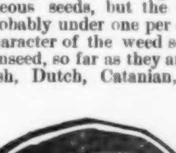


Fig. 23.—*Silene species*.—Ionian.

seeds found in it appear to be characteristic, and are represented at Figs. 23 and 24. The first, Fig. 23, is a minute, brown, kidney-shaped seed, somewhat flattened, and which can only by the aid of a lens be observed to be marked with concentrically arranged warty points. Fig. 23 is a lens-shaped seed like a lentil, and of a yellowish color. It also contains a few of the grass seeds, Fig. 1, and some small black caryophyllaceous seeds, but the whole of the weed seeds present are probably under one per cent.

The chemical character of the weed seeds present in the different kinds of linseed, so far as they are known, seems to point to the English, Dutch, Catanian, Ionian, and Ner-

Fig. 24.—*Ervum species*.—Ionia.

budda varieties of linseed as the best for use in pharmacy and oil painting, these kinds being most free from cruciferous seeds. The Riga seed, when properly sifted, is acknowledged to be the best for producing flax, and the other kinds are suitable only for making cake and extracting inferior qualities of linseed oil. The cruciferous seeds, unless present in large quantity, probably act only as a stimulant; in linseed cake the *Spergula arvensis* and the polygonaceous seeds contain chiefly farinaceous albumen, the former being recommended in works on agriculture as a stimulating food for poultry, while the latter are nearly allied to buckwheat, and possess probably the same nutritive properties.

* *Agri. Hort. Journ. India*, ii. 449, iii. 56.

It must not be supposed that the weed seeds above represented are the only ones which occur in different samples of linseed; only the most characteristic and those present in the largest quantity have been noticed. Dr. Voelcker found more than twenty-five kinds of weed seeds in linseed, and Dr. T. Nobbe in his "Handbuch der Samenkunde," p. 439, gives a list of forty-one species, only eight of which, however, were present to the extent of more than one hundred per kilogramme, the highest number of any one kind present being 39·51 per kilogramme in linseed containing 6·91 per cent. of foreign seed.

Nor must it be concluded that linseed oil owes its impurities solely to the presence of foreign weed seeds in the linseed, since resin oil and certain paraffin oils are well known to be used to adulterate it.

In conclusion I have to express my thanks to Professor Dragendorff, Mr. T. Greenish, Mr. J. Baynes, of Hull, and Mr. Cocksedge, for numerous samples of linseed from different countries; and to Professor Bernardin, Mr. J. R. Jackson, of Kew, Mr. Kemp, of the Linseed Association, and other gentlemen, for much interesting and valuable information.

THE ARMY WORM.

According to one of the annual reports of Mr. C. V. Riley, the insect which, in 1876, attracted most attention in Missouri, after the terrible devastations of the Rocky Mountain locust, was the army worm, which committed great ravages during the summer of that year.

The name "army worm" is naturally applied to insects whose larvæ assemble together, and travel in immense numbers, comparable to the troops of a devastating army. There are several insects known by this name, but the true army worm is the larva of a moth belonging to the tribe *Noctuellidæ* and genus *Leucania*. Up to 1861, in the absence of any publication of a scientific character on the subject, our ideas in regard to this insect and its habits were very vague. At that time a few observing farmers announced that the appearance of the moth and its larvæ occurred when a very wet summer followed after several very dry ones. This was a fact based on experience, but the reason for it was unknown. It was known, too, that the larvæ attacked cereals and the grasses of the meadows, that they always appeared in troops, and that they disappeared as mysteriously as they had arrived.

The great damage that they caused in 1861 attracted the attention not of farmers only, but of distinguished entomologists like the late Dr. Walsh, Professor Thomas, the late Dr. Fitch, etc.; and, through the observations of these gentlemen, and the subsequent ones of Mr. Riley, the history and habits of the insect are now pretty well known. In order to understand the history of the army worm it is necessary to examine the three phases through which the insect passes, and which are represented in the accompanying engraving.

The *larva*, or "army worm," properly so called, varies considerably in color and size, owing to age and locality, but its characteristic markings are so constant as to make it readily distinguished. It varies in length from less than an inch to one inch and three quarters; is of a dark gray, with three narrow yellowish stripes above, and a broader one of the same color, or slightly darker, on each side; thinly clothed with short hairs, which are longer and somewhat thicker on and about the head, the latter being of a polished honey-yellow, with a network of fine dark brown lines and a black line on the front, like a reversed V.

The *pupa* is of a mahogany-brown color, nine lines in length, and tipped at the end with a short spine. Like the larva, it varies in size according to locality.

The moth, which was first described by the English entomologist Haworth in 1810, as *Noctua unipuncta*, but was afterwards placed in the genus *Leucania* along with the specific name given it by its first describer, is very plain and unadorned in its appearance. The eye, on first glancing at it, only recognizes it as an ordinary-looking moth of a tarnished yellowish-drab color, inclining to russet, with a small white dot near the center of its fore wings, and a dusky oblique stripe at their tips. On coming to examine it more particularly, we find it to be less than an inch long to the end of its closed wings, or, if these are extended, it is about an inch and three quarters in width, different specimens varying somewhat in size. Its forewings are sprinkled with blackish atoms, and at a short distance forward of their hind edge they are crossed by a row of black dots, one on each side of the veins. Outside of the middle of the wing this row of dots suddenly curves forward, and from this curve a dusky streak runs to the top of the wing, the ground-color being more pale and of a clearer yellow along the outer side of this streak.

THE ARMY WORM.—LARVÆ, PUPA, AND MOTHS IN AN OAT-FIELD.

Passing over the ravages committed by the larvæ of the moth in this country for some years past, accounts of which have appeared in full in various papers, we close this description with the following methods of destruction as practiced with more or less success in the Eastern States:

When the army worms are numerous it is desirable to arrest their ravages; the most common and probably the easiest method of doing this is that commonly practiced, *i. e.*, plowing a double furrow around the field, or across any part of a field toward which they are marching. It is necessary to have the steep side of the furrow next the unharmed crop, so that when the worm attempts to climb over, it may fall back into the furrow. Running the plow once in the furrow is not sufficient; twice and even thrice is better, and it requires to be renewed if washed down by rains. If the soil is stiff or stormy the worms will creep over the steepest ridge; it is on light, friable soil only that the ridge will suffice to protect the field. The foothold of the worm must give way, thus rolling it back into the furrow. Even under the best conditions of soil it is best to have two furrows, one about the width of a row of corn from the other. The worms thus trapped should be destroyed by fire or hogs. Laying dry straw in the furrows and then setting it on fire is a good plan, for by this means the soil of the furrow is made more friable. Thousands of the worms may be easily destroyed in a meadow by running a heavy iron roller over it. A very small pressure is sufficient to burst their skins, and the least injury of this kind will kill them. Of course this method will not succeed well where the ground is rough or uneven, since the worms always take refuge in the hollows. As soon as the crop is removed from the infested field, hogs, chickens, and turkeys should be turned in. Ducks also will do a great deal of good by searching for and eating the caterpillars. Sheep turned into the field will kill many of the worms by tramping upon them, especially if the flock is large.

Where the invasion of the worm is not very extensive, such methods, as before stated, have been found to succeed very well, but in some cases the incursions of the pest have been so formidable and overwhelming that the farmer has been powerless to avert the complete destruction of his crops.

POULTRY FARMING.

Poultry farming, if conducted on a sufficiently large scale, is very remunerative; but in order to obtain the best possible results and profits, it must also be conducted rationally, that is, with a thorough knowledge of everything pertaining to fowls: their stalls and coops, the food, and the market value of the different kinds of birds, etc.

Much valuable information, with excellent engravings, is given in a recent German poultry book, namely, Edward Baldamus' "Illustrirtes Handbuch der Federviehzucht" (Illustrated Hand Book on Poultry Farming), illustrated by Prof. Bürckner. We have copied therefrom some of the illustrations of the principal classes or families of poultry. By crossing the domestic hen with cocks of better classes, the quality of the flesh of the birds has been vastly improved and the number of eggs obtained has been increased.

The gold spotted Padua hen, shown in the upper right-hand corner, is well built and handsomely marked. The comb is very much deformed, and the chin flaps have disappeared entirely. The hens can be raised as well in coops as in larger spaces, produce a pretty fair quantity of eggs and flesh, and are great favorites with the ladies and are kept as a handsome fancy bird.

The Seabright, or gold and silver fringe bantams, shown in the lower right-hand corner, are probably the greatest triumphs of poultry breeding. They lay large quantities of eggs, the chicks can be raised easily and are hardy, and the cocks are courageous and daring.

The Transylvanian bare necks are especially well adapted for fattening, but also lay large quantities of eggs. They are excellent breeders, are frugal, and can stand rough climate and weather, and thus combine all advantages that can be demanded of a hen. They distinguish themselves from all other hens by the peculiar appearance of their neck, which is entirely devoid of feathers.

The Turkish or Sultan's hens have a large full hood, which is the main ornament of this handsome race. They are smaller than the Padua hen, are very lively, but have no good constitution, and can only be raised with difficulty. The hen lays large white eggs, but is a very poor brood hen. As this bird is not very voracious and does not scratch much, it can be kept on lawns which are to remain green for a long time.

Among the ducks the Aylesburies must be mentioned before all others, as it is so very well known and is raised in many parts of the world. It originally came from Buckinghamshire. Its advantages are its hardiness, size, and premature development. It acclimates itself very easily, and can be raised in countries where all other races have failed.

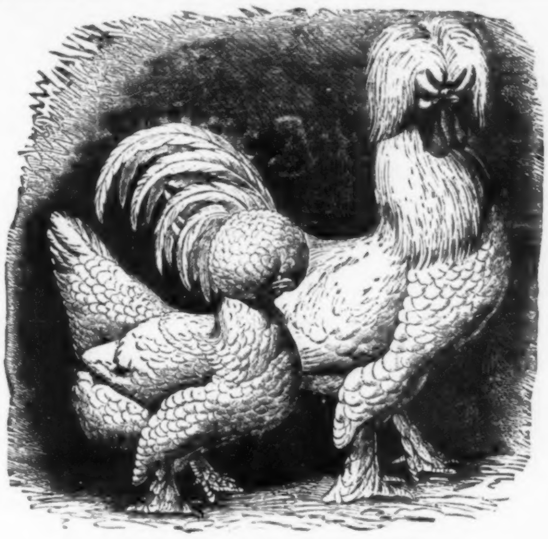
The Toulouse goose supersedes all others. It is of compact form, the upper parts are light gray, with lighter shades toward the back; the wings, breast, and abdomen are light gray, gradually passing into white toward the anus. The Toulouse goose fattens rapidly and perfectly, and sometimes attains a weight of twenty-five pounds.

In poultry farming the pigeon is the least remunerative, especially the fancy stock, from which no direct profits can be derived by the sale of eggs and flesh, but they bring very high prices from fanciers. The nuns are very handsome little birds, and are a result of care and patience combined, which triumphs in the production of accurate and careful marking of the birds. They have been named nuns on account of their peculiar head gear, which resembles that of a nun. There are black, red, yellow, and blue nuns, of which the black nuns are preferred in England, whereas the yellow and blue have the preference in Germany.

The Turbits are quite large and most beautifully marked in deep and shining colors of black, red, and gold. Besides these three colors they also appear in blue, blue spots, silver color with brown and black collars, silver red and yellow spots, others with red and yellow collars, and also very light brown. The characteristic feature is the marking of the head ornament.

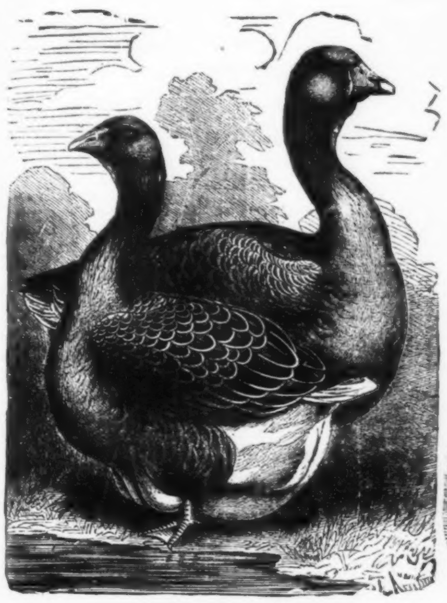
The red English pouter is really a caricature of a pigeon. Its peculiar feature consists in its crop, which must be as spherical as possible and must project on all sides except on the back of the neck, but especially in front, so that the beak will be partly hid in the feathers. The young bird does not begin to show the projecting crop until it is three or four months old.

The frill back has either a smooth head or a shell hood.

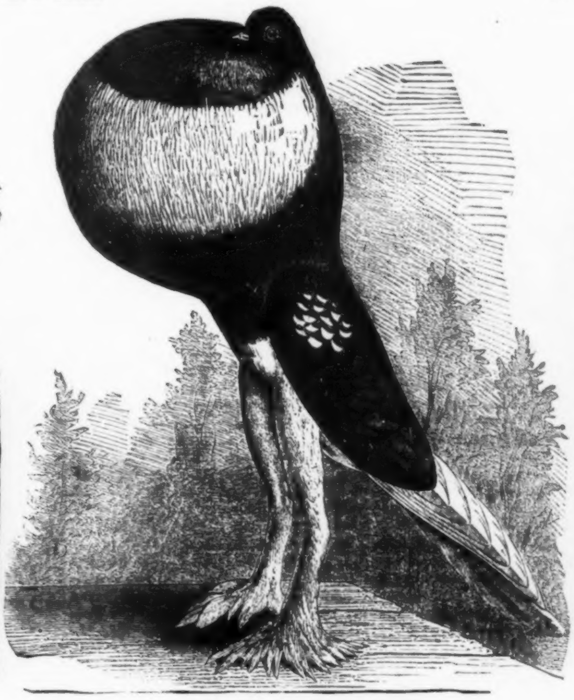


TURKISH OR SULTAN'S HEN.

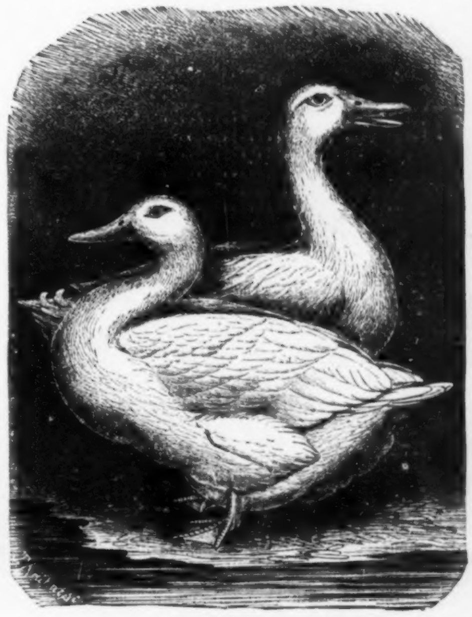
GOLD-SPOTTED PADUA HENS.



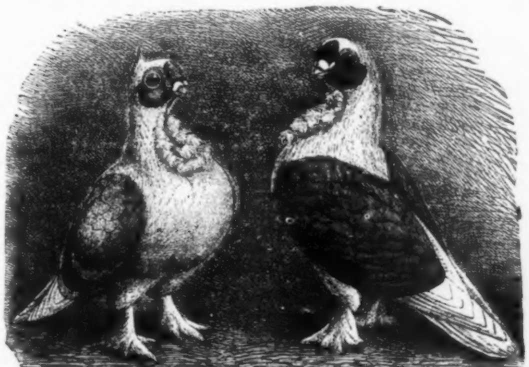
TOULOUSE GOOSE.



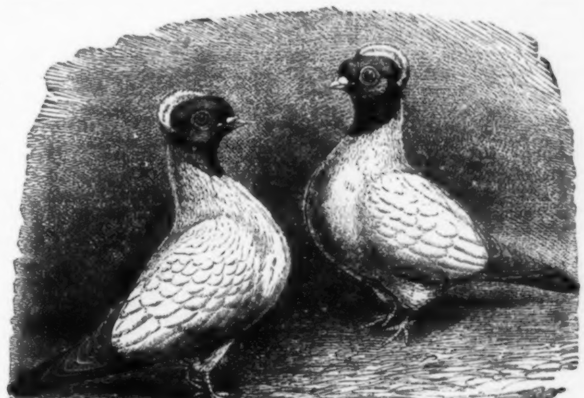
RED ENGLISH POUTER.



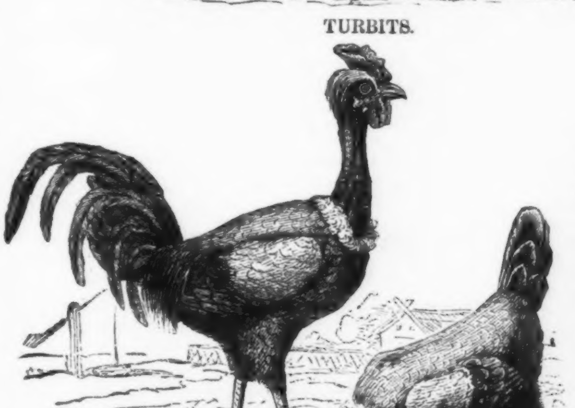
AYLESBURY DUCK.



TURBITS.



NUNS.



TRANSYLVANIA BARE NECKS.

FRILL BACKS.

SEABRIGHT BANTUMS.

EXAMPLES OF RARE POULTRY RAISED IN GERMANY.

It is of the size of an ordinary pigeon, and the feathers are turned upward or in the reverse direction. Generally the feathers on the head, neck, and back are only slightly frilled, but the other feathers, especially those of the wings, are beautifully curled. The colors are white, black, gray, generally with smooth head and sand colored, which have the most beautiful curls.

TIMBER TREES FROM SEEDS.

THE value of timber trees, planted in belts and in artificial forests, is becoming better understood as the country is gradually denuded of its natural growth. A check is given by failures in obtaining the young trees from seed, or by the expense necessary in purchasing large numbers of seedlings. Under proper management, however, many will be able to make their own plantations at a moderate cost, and a few suggestions under this head may therefore prove useful to those who have the time to devote and the determination to succeed in what they undertake.

There are a few causes of common failure which should be pointed out. One is in poor seeds, or those which have become too dry to germinate. Another is an insufficient preparation of the soil, or in burying the seeds too deep, or in not shading the more delicate of the young plants. Again, when planters gather their own seed, they do not always secure it at the right period. At the present time in autumn, when a large number of forest trees are maturing their seeds, some particular hints on this point may save our younger readers from failure in their experiments.

In planting such large fleshy seeds as chestnuts, acorns, horsechestnuts and beechnuts, the most common cause of want of success is allowing them to get too dry. As soon as they ripen and fall, therefore, which is usually about the middle of autumn or soon after, they should be gathered and kept slightly moist and fresh till they germinate. They might be planted at once, and the surface of the ground protected from drying winds by moss or evergreen branches were it not for mice, which show much skill in finding everything of the kind. A light covering of straw is still more certain to attract them. The safest way, therefore, is to pack them in damp sand or slightly damp moss, and place them in a cold cellar or other cool place till early spring planting. As they sprout very early they need not be planted deep; they will have moisture enough until they have thrown down their roots into the soil, if buried with only an inch of earth. The hickory and walnut are to be treated similarly, except that somewhat more care is necessary to prevent drying, as the thick shells serve as partial protection. But after the exterior covering of either chestnuts or walnuts has dried so long that they become hard and impervious to moisture from without, it will be useless to plant them.

The maples are of two classes—those which ripen their seed the first of summer, like the red and the silver maples, and those which do not ripen till October, as the black and the sugar maple. The former will supply well matured seeds three weeks after the leaves have expanded, and as they soon lose the power of germinating, they should be planted at once in finely pulverized soil, not over an inch deep—if moist enough, half an inch would be better—and if hot, dry weather follows, they should be partially shaded from the sun's rays. But seeds of the sugar maple, maturing in October, may be kept in damp sand in a cool place and planted early in spring; or if properly protected as above mentioned for nuts, they may be planted in autumn.

All the elms ripen seeds quite early in the season, and if sown shallow at once in fine mellow soil, they will make a good growth and be a foot high in autumn. White ash seeds, which mature early in October, may be treated like the seeds of the sugar maple. The same treatment may be given to the tulip tree and the basswood. The catalpa ripens plenty of seeds in its long pods, and these are easily kept, and planted the next spring they grow freely. The birches have small seeds ripening in summer or autumn, and when sown the following spring require good care, as the fine earth must be thinly sifted over them and kept sufficiently moist to insure germination; and the young plants may need the protection of shade under a hot sun. It may be cheapest for the inexperienced to buy the young plants by the thousand of nurserymen.

Seeds of the common locust and the honey locust will keep several years if quite dry. The common locust seeds require scalding to make them germinate. Put a quantity in a pint or quart basin, pour on boiling water and let it cool. In a few hours a part will be found swollen to double size. Pick these out and plant them at once an inch deep and they will grow. Repeat the process successively on the remainder until all are swollen and planted. Without this scalding process, the seeds will remain for years unchanged in the soil. The honey locust does not require this treatment.

The poplars and willows grow freely from cuttings, and are rarely raised from seed.

Conifers require more skillful management than deciduous trees, and it is commonly cheaper to buy the young trees, or seedlings, of nurserymen. A few suggestions are, however, offered to those who would attempt the experiment. The larch is perhaps the easiest to raise, but the seeds should be fresh and good, as they will not keep a year. The cones of the white pine drop their seeds about the first of October, and they must be gathered in time to secure them. The Norway spruce (now so largely grown of bearing size) matures its cones late in November, and they must be saved before the seeds fall out. The same may be said of the native black spruce. The seeds of conifers often require a month to germinate and come up. They must have the soil finely and thinly sifted over them, and the young plants always require more or less shading.

The berries of the red cedar are to be gathered late in autumn, mixed with an equal bulk of moist sand, and planted at once, or early the next spring. Most of them will grow the second year. We have always found them to succeed best by washing the pulp from the berries, although it is usually not regarded necessary by nurserymen.

The seeds of most evergreens being quite small, a great number of plants may be raised from a small quantity, if the seeds are good and fresh, and most of them grow. A pound of seed of the white pine contains 20,000; of the Scotch pine, 69,000; of the Norway spruce, 58,000; of the hemlock, 100,000; of the European larch, 60,000 to 75,000; and of the American arbor vitæ, 320,000. It will usually be much cheaper to buy evergreen seeds than to collect them, but the latter mode will be sure to secure them fresh. Many other seeds of trees may be gathered advantageously by those who desire to make plantations, and in this way fine collections of young trees are obtained at small expenditure.
—*Country Gentleman.*

RAINDROPS, HAILSTONES, AND SNOWFLAKES.

THE usual Saturday evening lecture of the meeting of the British Association was delivered by Prof. Osborne Reynolds, who said that the subject of his lecture had not until recently been the subject of careful investigation, for certain explanations of these phenomena, dating very far back, and he might say founded on guesswork, had never been accepted as satisfactory and sufficient. His object that night was to set before them the definite and rational history of the origin of these objects. He might call it the scientific history, for it was founded on the observations of physical laws, as well as tested by experiments which he hoped to put before them. The origin of his own special interest in this subject was the actual observance of what was open to every one. It was not till he was of mature age that he knew what really was the form of the ordinary hailstone, and this appeared to have escaped observation previously. He then explained that the form of the hailstone was that of an inverted umbrella, they were of a definite and exact form, in the shape of a cone having a rounded base and somewhat ribbed side. The lecturer showed a diagram illustrative of this description, and proceeded to explain the natural growth of these bodies. To apprehend that cloud or fog was formed by small definite particles or globules of water distributed through the air required no effort of the imagination. But when they came to inquire into the shape, size, and number of these particles, and as to their manner of suspension, there were certain difficulties before them. Let them start, for example, with the air in the hall in which they were assembled, presuming, of course, that it was clear air. In this air, strictly speaking, there was no water in the form of water, but there was water in the form of clear steam—gas as clear as air. The apprehension of this universal presence of steam in the lower strata of the atmosphere was the very foundation of the knowledge of meteorology. The amount of steam present depended almost entirely on the temperature. At the normal temperature of 60° Fahr., there were about six grains of steam in each cubic foot of air, or about a grain in a gallon. If the air were cooled to 30° there would only be present half as much steam, and the question was as to what would become of the other half. It would take the form of water which would be distributed through the room much as the steam was, but not exactly. The change from steam into water meant the congregation of the molecules into masses. It was obvious that a molecule of water at one end of the room could not get to the other end at once. What happened in the case of condensation of steam by the cooling of the air was very much the same as what would happen in the case of a regiment of infantry, in skirmishing order, being surprised by a regiment of cavalry. They would run into small knots in the best way they could. What happened when the air was cool was much the same. The particles which formed the water ran together into small groups, and formed those larger particles which constituted a fog. It was important to notice that there was a good physical reason which prohibited these elementary particles attaining more than a certain size. What they call the mean path of a molecule, or distance which a steam molecule was moving about, practically limited the size of the water particle which was formed on the first condensation. These congregations of water-particles were for the most part extremely small. He then proceeded to explain what were the causes of cooling air, one of which was the air coming in contact and mixing up with colder air. This was the common cause of dew at night and very commonly of the clouds above. But the main cause of the cooling of the air was the result of what scientists called expansion, or, as he might describe it for his own purposes, the ascension of air from a position near the ground up to higher positions among the surrounding air. The summer storms, to which he called particular attention, as affording the best evidence of this phenomenon, might obviously be traced to the ascension of a column of air which had been warmed by the ground, ascending much in the form of a column of smoke, and as it rose and expanded it became cool. It was merely the ascension which brought about the cloud, and the conclusion was that if we had layers of color in the air so as to see what was going to happen, all those white flocky clouds would declare themselves to be nothing more than the higher points of a lower stratum of air. This was the case with summer storms in particular. In this way huge masses of cloud are formed. These clouds reached several miles in thickness. Indeed, we are apt to take a very poor idea of the size of clouds owing to their height and their distance. As to the particles of which he had been speaking, the first question was why they did not settle down. The fact was, however, that they did descend, but very slowly. He asked them to imagine a particle of two diameters descending, and then to imagine a particle of one diameter descending. They would both descend until the resistance of the air amounted to the same effect as their weight. That fact was pretty well known, but it was not until Prof. Stokes clearly showed that the resistance of the air was proportional to the velocity at which the particles were descending, that it was clear that the particles would descend with the velocities proportional to their diameters. The ordinary size of a raindrop was very small. If they imagine a particle the size of a raindrop, it descended with obvious velocity, but if they took a particle the size of a fog particle, if they diminished the velocity by one hundred, they would get a comparatively smaller velocity. He could not actually show the size of the particles—they were too small to put in his lantern, but he showed them as an analogous phenomenon, extremely small particles of air ascending in fluid. They were literally like particles of a fog descending. The point to which he next asked their attention was why those particles do not fall suddenly and completely down, or why they aggregated and formed a raindrop. The real point of his lecture had been to explain how it was that those separate particles which they saw in the clouds came together and formed raindrops. The size of a raindrop was usually over-estimated, but it was a large raindrop that was one-sixteenth of an inch in diameter, while an ordinary raindrop was not more than a thirty-second part of an inch in diameter. But as to the question how it was the particles in the clouds came together and formed a raindrop: the larger particles descended faster than the smaller particles, and, sweeping them up in their descent, fell to the earth as raindrops. That was the key to the whole subject. If it were not for the large particles descending faster than the others, the whole of the particles would descend like a regiment of soldiers, and though they would never form rain they would come to the earth in a dense and perpetual fog. The manner in which the particles became united was not so well ascertained; indeed, he did not know that electricity might not have something to do with it. This was one of the explanations why clouds sometimes rained and sometimes did not. Cloud particles falling through a dense cloud for 1,000 feet would acquire the size of one-sixteenth of an inch in diameter, which was the size of the largest raindrops. Enlarging further on this subject, the lecturer said that clouds were often four or five miles in thickness. He then lucidly spoke on the following topics: Why do we not have larger raindrops; why do drops take the form of spheres at all; and what keeps them in the form of drops? By experiments, he showed the accumulation of particles into a drop, and the falling of a shower of rain. Some of these experiments, he explained, had never been shown to a large public audience before. The next topic treated of was capillary attraction—that which held the drops together, and caused water to rise up in small spaces. This showed conclusively that the surface of water was of a certain definite tension. The lecturer then proceeded to explain that when a raindrop exceeded a certain size its tension was insufficient to sustain it, and it fell and burst by virtue of the pressure against it. If it were not for this they would have drops amounting in size to the larger hailstones which sometimes fell. It would be a new phenomenon to have raindrops an inch or two inches in diameter, and what would be the result if it did happen might better be imagined than described. The fact that ice particles would stick together was not at first obvious; but a little consideration at once showed that that must be. With regard to the shape of hailstones, he said the conclusion generally come to was that that form was the result of the breaking up of a larger spherical stone having a vertex of the cone in its center.

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